SCIENTIFIC AGRICULTURE

Vol. XX NOVEMBER, 1939 No. 3

FURTHER STUDIES ON OAT BLAST[1]

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[Received for publication October 19, 1939]

In 1935 a preliminary paper was published on the causes of oat blast (1) which presented data showing that lack of moisture and reduced light at a critical period during the early growth of the plants were important factors in the blasting of spikelets. It was also shown that late seeding and late tillers tended to favour the development of blasted spikelets, and further, that no relation existed between the percentage of blast and spikelet number.

The present paper deals with the effect of blast on yield and also on the question of varietal resistance to blast.

Much of the literature on oat blast has been briefly reviewed in the earlier paper referred to above. The only reference to work on this subject that has come to the notice of the authors during the past four years deals with the susceptibility to blast of many oat varieties. Rademacher (2) states that "Blast is dependent on a number of external conditions. The variation was considerable. Susceptibility to blindness of the individual varieties was very different and heritable. There appeared to be no correlation between slight susceptibility to blindness and any other character."

BLAST IN RELATION TO YIELD

In view of the economic interest in oat blast as affecting yield, an effort has been made to determine whether or not the two characters are closely associated. In 1938, 300 panicles from each of 5 varieties (all belonging to *A. sativa*) were chosen at random in a 10 rod-row plot, marked at heading time and the total number of normal and blasted spikelets on each panicle was recorded in the field. At maturity these panicles were harvested and after drying were threshed and weighed separately.

Panicles of each variety were classified into 4 classes according to blast percentage as follows:—0 to 10.0, 10.1 to 20.0, 20.1 to 30.0, 30.1 or more. Table 1 shows the actual distribution of panicles in the four blast classes.

It can be clearly noted from this table that the grouping of panicles carrying different percentages of blast is quite uniform in the case of Erban, but with Lasalle about one-third of the panicles fall in the lowest class. In the variety Victory, there is a tendency for a greater number of panicles

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TABLE 1.—DISTRIBUTION OF PANICLES IN FOUR BLAST CLASSES

Percentage blast	Number of panicles				
	Erban	Victory	Lasalle	Alaska	Eagle
Class 0 to 10.0					
0 – 1	5	10	124	26	5
1.1 – 2		1		2	
2.1 – 3	1	6	8	35	6
3.1 – 4	6	0	32	8	
4.1 – 5	2	4	3	8	4
5.1 – 6	1	3	10	16	3
6.1 – 7	6	2	17	17	4
7.1 – 8	4	3	2	10	6
8.1 – 9	5	2	8	13	5
9.1 – 10	5	3	9	10	7
Class 10.1 to 20.0					
10.1 – 11	1	5	8	9	1
11.1 – 12	12	7	3	14	6
12.1 – 13	15	4	2	8	5
13.1 – 14	2	5	6	10	1
14.1 – 15	7	5	4	9	
15.1 – 16	9	5	5	19	7
16.1 – 17	13	3	7	9	4
17.1 – 18	6	6	4	14	8
18.1 – 19	6	3	3	8	7
19.1 – 20	14	8	3	8	10
Class 20.1 to 30.0					
20.1 – 21	10	6	4	4	8
21.1 – 22	6	5	5	5	5
22.1 – 23	6	8	3	3	15
23.1 – 24	10	10	1	4	6
24.1 – 25	7	6	1	6	5
25.1 – 26	6	18	3	4	17
26.1 – 27	9	11	3	4	15
27.1 – 28	7	12	3	4	16
28.1 – 29	11	16		3	14
29.1 – 30	10	13	1	2	15
Class 30.1 or more					
30.1 – 31	8	14	1	1	14
31.1 – 32	6	9	1		11
32.1 – 33	8	11	2	2	5
33.1 – 34	11	3	1	1	8
34.1 – 35	10	12	2		12
35.1 – 36	6	10			7
36.1 – 37	9	7			5
37.1 – 38	3	7	1	1	14
38.1 – 39	4	10			7
39.1 – 40	4	3			3
40.1 – 41	8	7			3
41.1 – 42	1	6			
42.1 – 43	4	3			1
43.1 – 44	1	1			1
44.1 – 45	1	2			
45.1 – 46	1	1			
46.1 – 47	2	1			
47.1 – 48					
48.1 – 49		1			
49.1 – 60	1				
Total No. panicles harvested	290	298	290	296	296

TABLE 2.—THE AVERAGE TOTAL NUMBER OF SPIKELETS (FERTILE AND INFERTILE) PER PANICLE, THE NUMBER OF PANICLES, AND THE MEAN WEIGHT PER PANICLE FOR THE FOUR BLAST CLASSES IN EACH VARIETY

	Variety	0 – 10.0% blast	10.1 – 20.0% blast	20.1 – 30.0% blast	30.1% or more blast
Average total number spikelets per panicle	*Erban*	27.69	27.19	25.29	23.98
Number of panicles in class		35	85	82	88
Average weight per panicle		1.94 gms. $t = 3.54$	1.65 gms. $t = 5.60$	1.33 gms. $t = 5.27$	1.08 gms.
Average total number spikelets per panicle	*Victory*	41.64	44.62	41.00	37.59
Number of panicles in class		34	51	105	108
Average weight per panicle		2.26 gms. $t = 3.18$	1.82 gms. $t = 7.49$	1.22 gms. $t = 8.16$	.81 gms.
Average total number spikelets per panicle	*Lasalle*	30.81	30.36	27.48	29.50
Number of panicles in class		213	45	24	8
Average weight per panicle		2.01 gms. $t = 6.45$	1.58 gms. $t = 3.64$	1.25 gms. $t = 3.91$	1.07 gms.
Average total number spikelets per panicle	*Alaska*	40.18	37.45	36.21	35.00
Number of panicles in class		145	108	38	5
Average weight per panicle		2.12 gms. $t = 10.37$	1.52 gms. $t = 4.72$	1.25 gms. $t = 0.007$	1.17 gms.
Average total number spikelets per panicle	*Eagle*	45.12	44.00	37.08	34.92
Number of panicles in class		40	49	116	91
Average weight per panicle		2.19 gms. $t = 4.17$	1.82 gms. $t = 9.74$	1.33 gms. $t = 5.74$	1.12 gms.

For comparison with the calculated t values, the corresponding theoretical value found in Fisher's Table of t is 2.57, based on $n = \infty$ and a probability of $P = 0.01$.

to be grouped in the higher classes, whereas with Alaska the opposite is true. In the case of Eagle, there is a greater tendency for a grouping of panicles in the 20.1–30% class. These differences might be attributed to varietal resistance, maturity of variety, or to other factors.

In Table 2 the average total number of spikelets per panicle, the number of panicles, and the mean yield of those panicles are recorded for the four classes in each variety. It is readily noted that the average yield per panicle decreases in all varieties as the percentage blast increases. This decrease is very consistent.

To test the significance of these differences in yield from one class to another, the t value was calculated by a method in *Methods of Statistical Analysis* (3, p. 24) by C. H. Goulden. These calculated t values are recorded in the table between each pair of yields whose differences are being compared. In the case of Erban, as an example, the t value based on the yields of 35 panicles in the 0–10.0% class and 85 panicles in the 10.1–20.0% class is 3.54. Entering Fisher's (4) t table under N, we find that the value of 3.54 exceeds the highly significant mark of $P = 0.01$. All values except one exceed the $P = 0.01$ value of 2.57. In this one case, which occurs in the variety Alaska ($t = 0.007$) there is no significant difference between the yields in the two high blast classes. However, the number of panicles in these classes is very small, only five panicles carrying more than 30.1% blast. It is reasonable to assume that the samples were not large enough for comparison in this case.

The differences between the mean yields are significant on a probability much less than 0.01. This means that the probability of exceeding these calculated t values, purely by chance, is very much less than 0.01 or once in 100 trials. Hence the differences in yield between the blast classes can be called highly significant.

In considering the yield figure as obtained from the mean weight of the threshed panicles in each class, one may wonder how much the decrease in yield from class to class is due to increase in blast or whether some of it may be due to an actual difference in spikelet number. Because percentage blast is a relative quantity and because spikelet number varies from panicle to panicle, the effect that the spikelet number may have on yield should be kept in mind. To do this it is necessary to calculate the partial correlation coefficients between number of blasted spikelets and yield, keeping the total number of spikelets constant, *i.e.*, eliminating the effect of the total number of spikelets. This was done for each variety. Correlation coefficients were also worked out for number of blasted spikelets and total spikelet number; number of blasted spikelets and yield and total number of spikelets and yield. The multiple correlation coefficients denoting the effect of both the number of blasted spikelets and the total number of spikelets on the yield were also determined.

In Table 3 are recorded the total correlation coefficients while in Table 4 are shown the multiple and the partial correlation coefficients.

Since the number of paired values is large, the significance of the correlation coefficients was determined by the t test. In comparing the total correlation coefficients it will be noted that those for number of blasted spikelets and total number of spikelets are definitely not significant for the varieties Erban, Victory, Lasalle and Alaska, but that the coefficient

for the variety Eagle is significant on a probability approximating P = 0.01. It was brought out in the earlier paper that there was no correlation between amount of blast and spikelet number. From this study it appears that this is not so with the variety Eagle. However, the negative coefficients between number of blasted spikelets and yield are all very highly significant. Positive coefficients between total number of spikelets and yield are also highly significant for all varieties.

TABLE 3.—TOTAL CORRELATION COEFFICIENTS BETWEEN

Variety	No. of blasted spikelets and total no. of spikelets	No. of blasted spikelets and yield	Total no. spikelets and yield
Erban	+.0485	−.4508	+.5322
Victory	+.0745	−.4937	+.6177
Lasalle	+.0626	−.4088	+.5121
Alaska	−.0870	−.6192	+.7166
Eagle	−.1490	−.3348	+.8123

NOTE: r at 1% level of significance and 300 degrees of freedom, for comparison with values in Tables 3 and 4, is 0.1480.

TABLE 4.—MULTIPLE AND PARTIAL CORRELATION COEFFICIENT

Variety	Multiple correlation coefficients—No. of blasted spikelets and total no. of spikelets with yield	Partial correlation coefficients—No. of blasted spikelets and yield . . total no. of spikelets constant
Erban	+.7148	−.5644
Victory	+.8212	−.6878
Lasalle	+.6762	−.5143
Alaska	+.9506	−.8022
Eagle	+.8406	−.3711

In Table 4 the multiple correlation coefficients are positive and very significant. This shows that both the total number of spikelets and the number of blasted spikelets have a marked effect on yield and the two together have much more influence on yield than either alone.

In the same table are shown the partial correlation coefficients which are perhaps the most important of all. Hence the effect of the number of blasted spikelets on yield can be measured directly by allowing the number of spikelets to exert no influence. In all cases a very significant negative correlation is obtained showing that as the percentage blast increases the yield decreases.

To carry this work further and to find out more about the relationship between the three variables, the multiple regression equations were calculated according to the method outlined by Snedecor (5, p. 245). These were obtained for each variety, where E represents the multiple regression equation, and where X_1 and X_2 represent the number of blasted spikelets and the total number of spikelets, respectively. From these equations the expected yield can be calculated for any panicle, providing the number of blasted spikelets and the total number of spikelets are known. The

equations for each variety are to be found in Table 5. The regression coefficients indicate that in this sample of data (example variety Erban) the yield decreases 0.079356 gram with each blasted spikelet, but increases 0.060065 gram with each increase in total spikelet number. Both coefficients specify changes in yield quite independent of changes in the other independent variate.

To show exactly how much the yield was reduced by blasted spikelets in each variety, values were substituted in the above equations. For (X_1), comparable figures of 10 and 20 blasted spikelets were used while the total number of spikelets (X_2) was kept at 40 so the effect of blast alone on yield could be measured.

The difference in yield, due to a difference in number of blasted spikelets, allows the actual loss in yield per blasted spikelet to be calculated for each variety. The above data appear in Table 5.

TABLE 5.

Variety	Multiple regression equations
Erban	$E = +.341166 - .079356\ X_1 \quad .060065\ X_2$
Victory	$E = -.156526 - .084336\ X_1 \quad .056367\ X_2$
Lasalle	$E = -.075423 - .113817\ X_1 \quad .070619\ X_2$
Alaska	$E = +.068364 - .117261\ X_1 \quad .057299\ X_2$
Eagle	$E = -.170715 - .028191\ X_1 \quad .048769\ X_2$

Variety	Calculated gram yield per panicle—panicles having 10 and 20 blasted spikelets respectively		Average decrease in yield per blasted spikelet
	10 blasted spikelets	20 blasted spikelets	
	gms.	gms.	gms.
Erban	1.950	1.157	.079
Victory	1.155	.411	.074
Lasalle	1.404	.009	.113
Alaska	1.188	.015	.117
Eagle	1.500	1.216	.028

As would be expected from results of previous data in this paper, there is a marked decrease in yield due to an increase in number of blasted spikelets and the yield of some varieties is much more severely affected by blast than others.

The above data point to an association of blast and yield, and indicate that the total spikelet number (fertile and infertile) is not responsible for the decrease in yield as the percentage of blast increases. The fact that the yield is lowered as the number of blasted spikelets increases therefore, must be due to loss of spikelets through blasting.

The question often arises as to whether the fertile spikelets on a panicle affected by blast develop better as a result of there being fewer spikelets for the plant to nourish. The limited amount of data at hand dealing with this phase of the problem indicates that there is no increase in mean fertile spikelet weight from the lowest to the highest blast class, but rather that there is an adverse physiological effect on the remaining fertile spikelets.

If further study proves this assumption to be correct, the damage to a crop by blast may be attributed not only to the actual loss of spikelets through blasting, but also to a weakening of the plants carrying blast to such an extent as to prevent normal development.

It is hoped that further investigations on this problem may be published at a later date.

DISCUSSION OF RESULTS

Considering the large size of sample used in this study it was deemed advisable to group the blast percentages into classes. This provided a clearer picture of the relation between yield and blast than individual plant differences would have shown. When the plants in each variety were allotted to their respective blast classes and the mean yields of the classes determined, differences between classes were very evident and proved to be statistically significant.

Since it is reasonable to assume that in the higher blast classes there would be fewer fertile spikelets, it might be expected that the yield would be lower. Similarly, as is shown in Table 2, the yields decrease in inverse proportion to the percentage blast. Since it has been shown in Table 3 that there is usually no significant association between total spikelet number and percentage blast, it might be expected that the average total number of spikelets per panicle would be approximately the same in all blast classes. If this were the case, we could attribute the reduction in yield from the lowest to the highest blast class entirely to an increasing amount of blast. But since there is a tendency for the average total spikelet number to be lower in the higher blast classes, as is shown in Table 2, some of the differences in yield might be attributed to this factor.

From the partial correlation work it has been shown that after eliminating the effect of total spikelet number the correlation between the number of blasted spikelets and yield is still very highly significant. This makes it possible to conclude that there is a decided effect of blast on yield without regard to total spikelet number.

A critical examination of the foregoing tables shows several apparent anomalies that have not yet been discussed. The correlation and regression coefficients in Tables 3, 4 and 5 show marked differences among them. Eagle does not show as marked a relationship between blast and yield as do the other varieties. This is evident from the low correlation and regression coefficients for blast and yield in this variety. It seems that for any increase in blast there is a smaller decrease in yield in the variety Eagle than with other varieties (see Table 5), but there is a very marked relationship between total spikelet number and yield in this variety. In addition Eagle shows a relationship between number of blasted spikelets and total number of spikelets which the other varieties do not. The variety Alaska with high correlation and regression coefficients for blasted spikelets and yield, and total number of spikelets and yield, shows that the yield is closely associated with blast and spikelet number. Victory, Lasalle and Erban show a good association of the blasted and total number of spikelets with yield.

These data show therefore that blast has a decided influence on yield and that the yield of some varieties is more severely affected than others.

VARIETAL RESISTANCE TO BLAST

The references on this phase of the study of oat blast have been quite consistent in that the various workers have reported definite varietal resistance. This literature was also reviewed in a previous paper (1).

In observing the relative amount of blast on different varieties in any given year, it has already been pointed out that some varieties appear to be more severely affected than others. One might easily assume that this difference could be associated with varietal maturity. Earlier maturing varieties might be expected to escape the adverse environmental conditions favouring blast. In studying varietal resistance to blast over a period of years, it has been found that varieties consistently low in blast are not necessarily early maturing. On this basis environmental conditions alone could not account for varietal resistance to blast, and it would seem likely that genetic factors are responsible.

In Table 6 are recorded the blast percentages of eleven varieties for the years 1932 to 1935 inclusive. It may be noted that the amount of blast varies from year to year particularly when individual varieties are considered. These yearly differences must be due to environment.

TABLE 6.—BLAST PERCENTAGES OF ELEVEN OAT VARIETIES FOR THE YEARS 1932–35 INCLUSIVE

Varieties	Maturity	1932	1933	1934	1935	Total	Mean
Alaska	Early	18.0	4.6	15.1	8.2	45.9	11.47
Legacy	Med. early	11.7	23.0	17.1	17.1	68.9	17.23
Victory	Mid-season	23.3	24.1	13.0	17.5	77.9	19.47
Banner	Mid-season	23.5	26.6	24.9	17.7	92.7	23.17
Silver	Mid-season	23.6	25.1	20.8	17.2	86.7	21.67
Sovereign	Mid-season	21.1	18.9	27.4	24.2	91.6	22.90
Eagle	Mid-season	10.6	12.1	10.7	6.9	40.3	10.07
Brant	Mid-season	14.4	24.6	24.8	11.6	75.4	18.85
Cartier	Early	27.0	25.8	23.1	21.6	97.5	24.37
Lasalle	Mid-season	6.8	13.0	13.3	7.8	40.9	10.23
Gold Rain	Med. early	26.4	29.6	35.4	38.0	129.4	32.35
Mean		18.76	20.67	20.51	17.07		19.25

As referred to above, it is readily noted from Table 6 that there is no consistent association between maturity and percentage blast. For example, the two early maturing varieties Alaska and Cartier are not in the same class as regards blast susceptibility. Similarly Lasalle and Banner, which are both mid-season varieties, differ widely in the mean percentage of blast for the 4-year period.

Finally and more significant, the analysis of variance of the data in Table 6 shows that regardless of environment and maturity, varieties possess different degrees of resistance to blast. The analysis shows by comparison of F values that there is a highly significant difference between varieties based on the mean percentage blast for 4 years (F value = 8.67: 1% point = 2.84). A comparison of F values for between years shows no significant difference in the mean percentage blast for all the varieties from year to year. (F value = 1.77: 1% point = 26.12). The necessary difference in percentage blast between variety means to be significant

is 7.8%. Therefore, on the basis of this experiment, the analysis of the data shows the existence of different degrees of varietal resistance to oat blast. This conclusion confirms the findings of other workers and should offer encouragement to breeders in development of oat varieties resistant to blast.

SUMMARY

1. The presence of blast in the oat crop affects the yield, the actual loss bearing a direct relationship to the amount of blast.

2. No statistical relation exists between number of blasted spikelets and total number of spikelets (fertile and infertile) except for the variety Eagle. The correlation in this case is negative and significant.

3. A high positive correlation exists between total number of spikelets and yield.

4. It is shown by partial correlation that there is a strong negative correlation between number of blasted spikelets and yield.

5. Multiple correlation coefficients show that both the total number of spikelets and the number of blasted spikelets have a marked effect on yield.

6. That there is a negative relationship, independent of other characters, between yield and number of blasted spikelets and a positive independent relationship between total number of spikelets and yield has been confirmed by the use of the multiple regression equation.

7. In addition to the loss of spikelets and consequently a lower yield as the result of blast, there is an indication that the physiological conditions associated with the causes of blast may adversely affect the maximum development of the remaining fertile spikelets.

8. Regardless of environment and maturity, oat varieties possess different degrees of resistance to blast and from the data used in this investigation, it would seem that the degrees of resistance or susceptibility are controlled by genetic factors.

9. With similar amounts of blast, it appears that the yield of one variety may not be as severely affected as that of another.

ACKNOWLEDGMENTS

The authors are indebted to Dr. J. W. Hopkins, National Research Council, Ottawa, and to Dr. J. H. Torrie, Dept. of Agronomy, University of Wisconsin, for reading the paper and offering helpful suggestions, particularly in the statistical analysis of the data.

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DISTRIBUTION OF *FASCIOLA HEPATICA* LINN. AND ITS POTENTIAL VECTORS IN CANADA[1]

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[Received for publication, September 22, 1939]

Fascioliasis and the parasite causing it have been known under numerous and varied designations, those listed being of greater interest on this continent:

English: Rot, Rot dropsy, Liver rot, Fluke disease, Cachexia aquosa, Verminosa.

French: Cachexie aqueuse, Pourriture, Foie douvé, Douve, Jaunisse, Douve hépatique fasciole.

This parasite has been known for a long time, but the first authentic record is that of Jehan de Brie in 1379. At that time it was known in France by the name of "la douve." The origin of this name may be attributed to the early French shepherds who believed that a certain species of grass of that name, which grows on marshy land, on being ingested by sheep, became transformed into the common parasite, the liver fluke. Little did they realize how close they were to the true story and it was not until the early eighteen-eighties that the life cycle of this parasite was elucidated by Leuckart and Thomas, quite independently of one another. From then until the present time, severe outbreaks of fluke disease have occurred intermittently throughout the world—the more disastrous epidemics of Rot being reported in Great Britain and other European countries.

F. hepatica has been known to occur in North America for many years. Hall (5) refers to the early history of the disease in the United States in the following terms:

> "Gordon in 1883, quotes a letter from a sheep man in California who states that fluke disease ranks as the most fatal they have in that region. Curtice in 1890, states that flukes have been seen in California, and Stiles in 1902, notes that five per cent of the sheep along the Columbia River bottom were infected with *Fasciola hepatica* while seventy-five per cent of the sheep along the western slope of the Cascades in Oregon were infected. He further records its occurrence at Washington in the same year. Gordon in 1883, further states that a flockmaster of San Saba county reports in 1877 a loss of 1,198 sheep out of 1,515 by Rot."

It is apparent that by the end of the last century, fluke disease was widely distributed on this continent. However, most of the observations and records at that time were from the Pacific Coast and the Gulf States.

[1] Contribution from the Institute of Parasitology, McGill University, Macdonald College, Que., with financial assistance from the National Research Council.

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Francis (3) in one of the early bulletins of the Texas Agricultural Experimental Station, states that

> "This well known parasite occurs in the livers of cattle, sheep and goats in Texas, in sufficient numbers to cause great damage."

The early history of the liver fluke in Canada is unknown but it has probably been established since the early importations of sheep and cattle. The first definite record of *Fasciola hepatica* is by Hadwen (4) in 1916. In his synopsis on the ravages of the disease in British Columbia, he writes to the effect that

> This parasite has been endemic among the coast sheep of that province since the early settlements. Although the economic losses incurred at that time did not compare with those of other European countries, flockmasters suffered considerable losses and some tracts of low ground, where sheep-raising had been practised, had to be abandoned.

It was not until 1929 that this parasite was recorded from the Lower St. Lawrence River Valley. The fluke has since been obtained from the north and south shores of the river in the vicinity of Quebec City. Its presence in livers from that area was well known by the local inhabitants, but until 1929, identification of this parasite was not established.

During the next few years, an attempt was made to ascertain by correspondence whether any outbreaks of fascioliasis had occurred recently in Eastern Canada. No definite information leading to new records of distribution was received, but during the latter part of 1934, suspicious material was obtained from an abattoir at Moncton, New Brunswick. The material received had been diagnosed as fluke-infected liver. A few lesions were present and on sectioning these showed considerable formation of fibrous tissue, probably due to previous migration of young flukes through the liver tissues. The lesions did not present the usual clinical picture of fluke infestation, but on examination of the washings of the bile ducts, numerous ova were found present. Although some of the ova were distorted, upon microscopic examination, they resembled the ova of *F. hepatica* in all respects.

From this material, it seems justifiable to conclude that the fluke is present in the neighbourhood of Moncton, and that with further investigation, it might be shown to be quite widespread in that section of the country. This belief is based on the report that, at certain times of the year, quite a number of livers, showing similar lesions, are reported to be received at that abattoir.

In 1934, specimens of *F. hepatica* were received from Langley Prairie, B.C., but at the present time, the fluke does not appear to be common or to cause any serious losses in this province. It has been recorded from sheep and cattle. All cases appear to be confined to the coastal region. It has yet to be reported from the Prairie Provinces and Ontario.

On account of the geographical similarity, the extent of boundaries and the vastness and immensity of inland waterways, it seems practicable to consider Canada and the United States together, for the purpose of discussion on the intermediate hosts of *F. hepatica*.

Throughout the United States, *F. hepatica* has a comparatively widely recorded distribution and during the last few years, several snails have been incriminated as carriers:

Mollusc	*Investigator*
Lymnaea (G.) bulimoides Lea	Shaw & Sims, 1929.
Lymnaea (G.) bulimoides techella (Haldeman)	Sinitsin, 1929.
Lymnaea (G.) cubensis	Van Volkenberg, 1929. Hoffman, 1930.
Lymnaea (G.) ferruginea Haldeman	Shaw, 1931.
Fossaria modicella	Krull, 1933.
Pseudosuccinea columella	Krull, 1933.
Lymnaea traskii	Krull, 1934.

Up to the present time, the vector of this parasite in Canada has not been proven. The distribution of the suitable snails is such that it is possible for the trematode to occur in almost every province. Snails shown to be vectors in the United States and elsewhere are distributed in Canada as follows:

Yukon	*Lymnaea (G.) truncatula.*
British Columbia	*Fossaria ferruginea*
	F. modicella.
	Lymnaea (G.) bulimoides.
Alberta	*F. modicella*
	L. (G.) bulimoides.
	L. traskii.
Saskatchewan	*F. modicella.*
Manitoba, Ontario, Quebec	*F. modicella.*
	Pseudosuccinea columella.
New Brunswick	*P. columella.*
Nova Scotia	*P. columella.*
	F. modicella.

This distribution of molluscs was obtained from Baker (1, 2) and by personal communication with A. La Rocque of the National Museum of Canada, Ottawa. It will be observed that the potential vectors of *F. hepatica* in Canada are distributed from coast to coast.

The Galbas are more terrestial than other Lymnaeas; they are often found on wet banks or on bars of mud, in old tracks and hoof marks, and frequently in places some distance from water. The Pseudosuccineas, however, tend to inhabit ponds and streams where the water is more or less stagnant; they favour a locality with many lily pads, shallow water, cat-tails and other reeds, seldom being found in running water. The Fossarias are likely to be found in small bodies of water such as creeks, ponds, sloughs, bays and marshy places along river banks or even in fast-running water over a gravel bottom, their colouration and markings rendering them difficult to see when attached to small pebbles beneath swift running water.

From this brief resumé of the habitat of these genera, it will be noted that the snails associated with *F. hepatica* may be found over a wide range

of types of environment. It should also be kept in mind that the habitat of any given species is subject to considerable variation by the environmental factors that may be found in any given locality.

ACKNOWLEDGMENT

I wish to record the invaluable assistance given to me in the identification of snails by Mr. A. LaRocque, National Museum of Canada, Ottawa.

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SOIL SURVEYS OF SASKATCHEWAN IRRIGATION PROJECTS[1]

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[Received for publication September 21, 1939]

Soil surveys of proposed irrigation areas in Saskatchewan were first undertaken in 1936, at the request of the Water Development Committee, operating under the Prairie Farm Rehabilitation Act. During the last three years 18 projects have been surveyed. The total area mapped in all projects was approximately 90,000 acres, while over 1,700 samples of soil were secured for laboratory analysis.

It is clearly impossible to deal adequately with all these surveys in a single paper. Furthermore, since the projects are still in the early stages of development, their crop adaptations and problems have not been fully determined. Hence the present study is limited to a discussion of the objectives and methods used in the surveys. It is hoped also to give some indications both of the value and of the limitations of the soil survey as applied to irrigation areas.

OBJECTIVES OF THE SURVEY

In requesting a soil survey of irrigation projects, the Water Development Committee were particularly desirous of obtaining the soluble salt content of the soils. Later, requests for soil ratings and other data were received from both Dominion and Provincial authorities. In general, however, the planning and conduct of the surveys has been the responsibility of the soil survey staff under the direction of Dr. J. Mitchell of the University of Saskatchewan.

The main purpose of a soil survey is to secure fundamental information on the soils and physical features of a given area. In the case of irrigation lands it is necessary, in so far as may be possible, to determine the suitability of each soil type for irrigation and to forecast potential soil problems.

It was realized that these objectives could not be accomplished by the soil survey alone. Many irrigation problems demand attention from both the engineer and agronomist. Furthermore the final classification of irrigation land must be based upon its actual productive capacity over a period of years.

Nevertheless it was necessary to attempt achievement of the above objectives, since there were no established irrigation schemes in the Province which could be used as a guide. And as even the more advanced projects were still under construction, there was an inevitable lack of much engineering and agricultural information.

With due regard to the above mentioned limitations, it was decided that the survey should secure the following data:

1. Classification of soils on the basis of profile characters.
2. Drainage and topographic conditions as related to soils.
3. Vegetation and land use as related to soil and drainage conditions.

[1] Presented at a meeting of the Western Canadian Society of Agronomy, Lethbridge, Alta., June 1939.
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4. Soluble salt content of representative soil samples.
5. Additional laboratory data as an aid to soil classification.
6. A grouping of the various soil types in order of irrigable value, based upon the foregoing studies.
7. General information concerning the climate, soils, physical features and agricultural development of the surrounding district.

As soon as the field and laboratory work was completed, a soil map and report were prepared for each project. In this way the data secured by the soil survey were quickly made available to those responsible for water development policies. It is hoped that further use may be made of the survey reports in time to come. In the first place, by checking the soil classifications with actual crop production over a period of years, it will be possible to arrive more closely at the relative values of different soil types. Secondly, by regarding the soil survey data as a record of the physical conditions existing prior to irrigation, a basis may be established for measuring the soil changes which inevitably follow irrigation developments. Such comparisons would not only be useful in dealing with problems of soil management but would constitute an interesting field of study to the soil scientist.

FIELD STUDIES

General Procedure

The surveys were conducted by a combination of car and foot traverses. Field maps were prepared on a scale of 4 inches to one mile, or larger. Engineers' plans and aerial photographs were used when available, but in many cases suitable base maps had to be prepared during the survey. The Brunton compass was used extensively to locate land boundaries, physical features and the sites where samples were taken.

Mapping Factors

All soil and land factors were shown in a composite 4-point symbol. This was an adaptation of the system used by the U.S. Soil Conservation Service (1). The kind and arrangement of factors used in the irrigation surveys are shown below:

$$\frac{\text{(Surface Soil)} - \text{(Topography and Drainage)}}{\text{(Subsoil)} - \text{(Vegetation and Land Use)}}$$

This system, with appropriate letters or symbols for each factor, makes it possible to indicate a considerable amount of data on the map in a very concise form. It also assists in securing uniformity of mapping methods. Finally it prevents the omission of essential data, since it is an established rule that each soil area must be indicated on the map by a completed 4-point symbol.

In addition to the factors shown in the composite symbol, soil classifications were indicated by a number placed within each soil boundary. The significance of the mapping factors is discussed below.

Soils

Soil types were separated on the basis of profile characters, correlated with factors of topography, drainage and vegetation. Particular attention

was paid to the texture of the soil, and the usual range of textural separations was increased. The heavy clay "gumbo" soils were classed as very heavy clays in order to distinguish them from the heavy clays of good structure such as the Regina and Sceptre types.

Due to the fact that most of the projects were situated on the flood plains of streams, the soils were chiefly derived from variable strata of alluvial deposits. Profiles were generally poorly developed and immature. Hence these soils did not fit into established series, except in a few places where upland types came under the ditch.

Topography and Drainage

While the final determination of topography was made by the engineer, it was necessary to consider this factor in dealing with soil and drainage conditions. Apart from river terraces, valley slopes, and islands of non-irrigable land, topography could be classed as nearly level to very gently undulating. Topographical separations were also made of the micro-relief. Depressional, smooth and hummocky conditions were mapped.

Drainage conditions, like those of topography, are primarily the concern of the engineer. Nevertheless drainage also has an important influence on soil development. In particular the internal drainage or relative permeability of the soil profile is a factor of first importance. Three classes of soil drainage were mapped in the field: well drained; moderately drained, with well drained surface and poorly drained subsoil; and poorly drained, including soils liable to flooding and those possessing high water tables.

Vegetation and Land Use

The vegetative cover could generally be related to the other mapping factors, and such plants as greasewood, sage-bush, salt grass and blue joint proved valuable indicators of soil and drainage conditions. Short combinations of letters were placed on the map to denote the dominant plant species.

Land use also correlated well with soil conditions. Cultivated land indicated that under dry farming conditions the soil was suitable for crop production. Appropriate letters were adopted to denote such land use as cultivated, pasture, hay, and abandoned or idle land. The factors of vegetation and land use also formed part of the data required as a record of the land conditions prior to irrigation.

Soil Classification

The classification of lands in order of irrigable value was based on a system for rating irrigation soils established by the Alberta Soil Survey. The method was modified slightly to fit Saskatchewan conditions. The ratings represent percentages assigned to each soil texture. Thus ratings of 90 to 100 are given to medium textured soils, while the lowest values are placed upon soils of extreme textures. However, while texture is the main consideration, such factors as organic matter, soluble salts, soil structure and drainage, etc., may modify the final rating.

The ratings were only shown on the map where the actual irrigable acreage of each parcel of land had been determined. In projects not covered by detailed engineers' plans the soils were classified into groups. While the system of ratings was used as a guide, the classification was extended so

that soils possessing general similarity in textures and potential crop adaptations could be placed in the same group. It is of interest to note that this method of classification agreed closely with actual conditions of crop production observed in the Milk River Valley, Montana. A study of the latter projects indicated that the physical factors were similar to those mapped in Saskatchewan.

Soil Sampling

The wide variations in soil conditions, and the fact that reports were desired immediately after each survey was completed made it impossible to sample the soil at close intervals. The aim was to secure samples representing the main soil groups, and particularly those considered to be of doubtful value.

The samples were taken by borings made with a 4-inch post-hole auger equipped to reach a depth of 6 feet. The samplings were made on a profile basis instead of at arbitrary depths. While the latter method is the more rapid it does not present a true picture of the soil conditions usually encountered. However in most cases surface samples were taken to a depth of 6 inches, in order to give a basis for comparing the organic matter and nitrogen contents of different surface soils.

In selecting samples the local conditions of topography, drainage, vegetation and land use were observed. The individual samples were collected on the basis of the following soil factors: depth of horizon or stratum, texture, colour, structure, consistence, effervescence with HCl, and moisture conditions. Other important features were noted when present.

LABORATORY STUDIES

Most of the laboratory work consisted of determining the soluble salt content of the soil. Total salts were determined on all samples and qualitative tests were made of important ions in solution. Carbonates and chlorides were titrated when present in sufficient amounts. Detailed analyses of the soluble constituents were made on a few selected samples.

In addition, pH values were determined on all samples, and organic matter and nitrogen on the surface soils.

Finally, percolation rates were determined on samples representing the main soil groups. The method adopted was essentially that of Slater and Byers (2), which gives the relative rate of water percolation through saturated soils. Such data are obviously not directly comparable to the rate of water intake under field conditions. Nevertheless the laboratory results generally agreed closely with factors of soil texture, structure and drainage. In particular the determination offers direct evidence of the differences which may exist in the character of parent materials of similar texture. Thus the poor physical condition of the "gumbo" soils as compared with Regina clay is indicated by a comparison of their percolation rates.

The large number of samples secured and the time factor previously referred to, prevented a more complete laboratory study being made. As a number of soil samples have been retained, it is planned to make additional studies when time permits. Determinations of exchangeable

bases, volume weight, moisture holding capacity, and the wilting coefficient would be of direct practical value to the irrigationist. It is possible too that attention should be given to the quality of the irrigation waters.

DISCUSSION

The material presented above covers the principles adopted in the survey of Saskatchewan irrigation soils. By way of comparison it is interesting to refer to some recent papers dealing with irrigation in the United States. Youngs (3) considers that physical factors have had the greatest effect on the development and degree of success or failure of irrigation projects. The basic physical factors are climate, soils, water supply, relief and drainage. In the American surveys observations are made of the results of irrigation farming on specific soil types. Where this is impracticable the soil is rated on the basis of natural factors. The two methods are combined wherever possible.

Hutchins, *et al.*, (4) state that land classification is of special importance in irrigated areas, and list three factors which must be given particular attention. They are: suitability of topography for economic distribution of water, freedom of the soil from excessive quantities of alkali salts, and adequate drainage facilities. According to these authors the most pressing problem for irrigation research is the concentration of salts in surface soils through the application of irrigation water.

Scofield (5) states that the greatest number of failures in irrigation projects have been due to unfavourable conditions of soil, water supply, and drainage which were not realized in advance. The trouble has resulted from inadequate information or failure to use the information available. He also suggests that a wider appreciation is required of the factors of soil, topography, and drainage. There is need too for detailed soil surveys and land classifications made prior to irrigation development. The soil solution and the quality of the irrigation water are given special attention by this author.

It would appear from the above statements that long experience has shown the desirability of studying soil and land conditions not only prior to irrigation, but throughout the life of the project. The soil survey may thus be regarded as a link between the work of the engineer and that of the agronomist. The initial task of making water available, and the final problem of using it to produce satisfactory crops, must inevitably be influenced by the character of the soil.

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DIGESTIBILITY STUDIES WITH RUMINANTS*

V. Associative Digestibility Among Roughages and Succulent Feeds

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[Received for publication September 8, 1939]

Associative digestibility is defined as a change in the digestibility of a feed due to its incorporation in a ration with one or more other feeds.

Credit for the introduction of the phrase, "associative digestibility" apparently should be given to Ewing and Wells (2). In 1915 they studied mixed rations composed of corn silage, cottonseed meal, and starch. A summary of their results for the corn silage and cottonseed meal is given in Table 1.[6]

Table 1.—Associative digestibility of corn silage + cottonseed meal,—Ewing and Wells (2)

Feed	No. of individual values	Statistic	Coefficients of digestibility (in per cent)		
			Dry matter	Organic matter	N-free extract
Corn silage alone	12	Mean	59.6	61.4	63.2
		Standard error	±1.12	±1.12	±1.47
		Coefficient of variation	6.50	6.33	8.08
Cotton seed meal alone	5	Mean	63.7	68.5	70.6
		Standard error	±1.76	±1.95	±3.22
		Coefficient of variation	6.19	6.37	10.2
Cotton seed meal calculated from ration with silage	16	Mean	67.7	70.2	71.7
		Standard error	±1.88	±1.50	±6.27
		Coefficient of variation	11.13	8.53	35.0

It will be observed that the values for the cottonseed meal calculated from the mixed ration with silage were higher than the values for cottonseed meal when fed alone. The differences were, however, not significant.

In a second paper, Ewing and Smith (3) investigated rations composed of corn silage, alfalfa, and velvet bean meal in various combinations and proportions. In the silage-alfalfa ration, silage-velvet bean meal ration, velvet bean meal-alfalfa ration, and silage-alfalfa-velvet bean

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[6] The data in Table 1 were not presented in that form by Ewing and Wells but were rearranged and computed by the authors of this paper.

TABLE 2.—COMPARISON OF OBSERVED AND CALCULATED DIGESTIBLE PROTEIN AND STARCH VALUES IN PER CENT OF DRY MATTER (MERTINS (9))

Ration	Digestible protein							Starch value						
	Sheep 1			Sheep 2			Mean diff.	Sheep 1			Sheep 2			Mean diff.
	Found	Calculated	Diff.	Found	Calculated	Diff.		Found	Calculated	Diff.	Found	Calculated	Diff.	
b_4—Clover silage, hay and straw	3.08	4.10	−1.02	4.04	3.93	+0.11	−0.46	29.9	33.8	−3.9	28.5	31.0	−2.5	−3.2
c_4—Corn silage, hay and straw	4.01	4.31	−0.30	4.03	4.29	−0.26	−0.28	38.0	38.7	−0.7	36.6	39.6	−3.0	−1.9
d_2—Potato silage and hay	4.69	5.25	−0.56	4.90	5.45	−0.55	−0.56	68.2	69.7	−1.5	59.7	63.8	−4.1	−2.8
d_4—Potato silage, hay and straw	2.87	2.97	−0.10	2.44	3.30	−0.86	−0.48	35.8	41.5	−5.7	34.1	42.8	−8.7	−7.2
a_2—Hay + concentrate	11.44	11.39	+0.05	11.11	11.33	−0.22	−0.09	39.0	38.9	+0.1	37.4	38.4	−1.0	−0.5
b_2—Clover silage + concentrate	17.51	17.37	+0.14	17.62	16.71	+0.91	+0.53	63.1	63.5	−0.4	60.6	59.8	+0.8	+0.2
c_2—Corn silage + concentrate	15.74	15.77	−0.03	15.38	15.46	−0.08	−0.06	59.6	57.8	+1.8	58.1	58.4	−0.3	+0.8
b_3—Clover silage, concentrate and hay	11 05	10.90	+0.15	11.06	9.97	+1.09	+0.62	51.9	47.0	+4.9	47.5	42.6	+4.9	+4.9
c_3—Corn silage, concentrate and hay	9.74	10.09	−0.35	9.97	10.50	−0.53	−0.44	44.1	46.1	−2.0	42.5	46.6	−4.1	−3.1

NOTE.—Values for concentrate mixture calculated from ration of potato silage + concentrate. Only one animal used in determining value for potato silage.

meal ration, the coefficients of digestibility of the dry matter, nitrogen, crude fibre, and nitrogen-free extract of the mixed rations were less than the values calculated from the coefficients of the individual nutrients. The differences were not great, however, being of the order of 2 to 4 absolute per cent.

Finally, in 1925, Ewing, Wells and Smith (4) continued the digestion studies of their first paper, namely, with corn silage and cottonseed meal. Due, however, to the large variation in the calculated values of cottonseed meal, it is difficult to draw any definite conclusions.

Mertins (9) conducted an extensive investigation on rations of clover silage, clover hay, straw, potato silage, and a concentrate mixture composed of equal parts of soybean oil meal, earth nut cake meal, sunflower cake meal, and wheat bran. The coefficients of digestibility of the four roughages were determined by feeding them alone. Values for the concentrate mixture were calculated from a ration with potato silage.

The results of Mertin's work as summarized by him are given in Table 2. For the four rations of mixed roughages, the observed values for digestible protein and starch values were slightly less than the calculated ones. The only marked difference was in the starch values of the potato silage-hay-straw ration. For the three rations composed of a roughage and the concentrate mixture, the observed coefficients agreed with the calculated. It must be noted, however, that the values for the concentrate mixture were not necessarily the true values but were obtained by calculation from a ration of potato silage and concentrate. Finally, for the two rations composed of two roughages and the concentrate, one gave observed coefficients higher than the calculated, and the other gave coefficients lower than the calculated. Mertins drew the general conclusion that for the practical calculation of mixed rations the simple addition of the values for the individual components should give satisfactory results.

Watkins (10) studied rations of wheat straw and cottonseed meal in which the meal was added at four different levels. By means of the method of least squares, the digestibility of the cottonseed meal was calculated from the various combinations with straw. Using these values for cottonseed meal, the coefficients of digestibility of oat straw were calculated from the various mixtures. These were compared with values for oat straw when fed alone. The coefficient of digestibility of the organic matter and the total digestible nutrients for the oat straw were higher in the mixture with cottonseed meal than when fed alone. However, the carbohydrates constituted 95% of the organic matter of the straw, and the digestibility of these was the same either when the straw was fed alone or when it was fed with cottonseed meal. Thus, it cannot be concluded that cottonseed meal influenced the digestibility of the straw.

It should be further pointed out that the values for the cottonseed meal were those that best fitted the experimentally determined values on the four different rations.

Other authors, notably Armsby (1) and Maynard, Miller and Krauss (8), determined the digestibilities of mixed rations, then compared them to the values obtained by using Henry and Morrison's tables. Such studies, of course, give no insight into associative effects.

From numerous digestibility studies in the literature, it is possible to select certain results from which values for individual feeds and mixtures of these feeds can be compared. Generally, however, since the investigations were not designed for the purpose of studying associative effects, it is not possible to draw definite conclusions.

For instance, Gramatzki (6) studied the influence of silage on the digestibility of nitrogen as well as on mineral balances. From his trials, it is possible to calculate that the coefficients of digestibility for the silage when mixed with hay were of the same order as when the silage was fed alone.

Forbes (5) in one of his trials on energy metabolism fed alfalfa and corn meal alone and then mixtures of the two. The values of the digestibility of the dry matter, organic matter and nitrogen-free extract of the corn meal calculated from the mixed ration tended to be higher than the values of corn meal fed alone. It was not possible to determine what significance should be attached to the difference.

Finally, in Hamilton and Mitchell's (7) study on soy bean products, there are opportunities for comparing the digestibility of mixed rations with the values calculated from the individual components.

In summarizing the literature, therefore, it would seem that there have been only two investigations carried out primarily for the purpose of studying associative digestibility. For that reason, a series of investigations was instituted to augment the present meagre knowledge on the subject.

EXPERIMENTAL RESULTS

In this paper data are reported on the associative digestibility among hay, corn silage, mangels, oat straw, and oat hulls. There are several ways in which an associative effect between any two feeds may be expressed. Consider the two feeds, A and B. In a mixture of these two, it could be assumed that the digestibility of A is the same as when it is fed alone. The digestibility of B, then, is calculated from the mixture under this assumption. If the digestibility of B, so obtained, differs from that observed when B is fed alone, then there has been an associative effect. This does not, of course, imply that in the mixed ration the digestibility of B has changed; it may have been the digestibility of A which has changed, or it may have been the digestibility of both A and B. It would be equally correct to assume that the digestibility of B remained constant, and to calculate the digestibility of A under that assumption.

A second method for expressing the associative effect would be to calculate the digestibility of the mixed ration from the digestibilities of A and B when each was fed separately. The result could then be compared with the digestibility of the mixed ration determined in actual experiment.

In the present case, the first method has been employed, namely, the digestibility of one of the feeds in a mixed ration has been assumed to undergo no change.

The coefficients of digestibility of the majority of the feeds for cattle, listed in tables and literature, have been obtained by calculation from a

mixed ration, generally with hay as a base. As has been stated before, the purpose of the investigations reported in this series of papers, is to determine the degree of reliability for feeding practices of such coefficients. It has therefore been considered quite logical in this paper to express associative effects by assuming that the digestibility of one of the feeds in a mixed ration has the same digestibility as when fed alone.

The material is presented in three parts, as follows:

I. The effect of the addition of oat hulls to hay, silage, and mangels.
II. The effect of the addition of straw to hay and silage.
III. The effect of the addition of hay to silage and mangels.

I. Effect of the Addition of Oat Hulls to Hay, Corn Silage and Mangels

A. Hay-Oat Hulls Combination

To determine the effect of the addition of oat hulls to hay, digestibility studies were carried out with the following four rations:

(a) Hay
(b) Oat hulls
(c) Hay and oat hulls in a ratio of 1 : 1
(d) Hay and oat hulls in a ratio of 5 : 3.

The animals were grade shorthorn steers, designated C, E, F, and G; animal C was $3\frac{1}{2}$ years old and weighed 518 kilos, whereas animals E, F, and G were $2\frac{1}{2}$ years old and weighed, respectively, 535, 470, and 460 kilograms. The experiment was set up in the form of a randomized latin square, as presented in Table 3. In the tables, the animals are designated by numbers I to IV.

TABLE 3.—SCHEDULE OF DIGESTION TRIALS FOR HAY-OAT HULLS COMBINATION, ARRANGED IN 4 × 4 RANDOMIZED LATIN SQUARE

Period	Feed	Daily ration in kilogrammes			
		Animal I	Animal II	Animal III	Animal IV
1	Hay	3.5	4.4	7.0	0.0
	Oat hulls	3.5	2.6	0.0	7.0
2	Hay	7.0	0.0	3.5	4.4
	Oat hulls	0.0	7.0	3.5	2.6
3	Hay	4.4	3.5	0.0	7.0
	Oat hulls	2.6	3.5	7.0	0.0
4	Hay	0.0	7.0	4.4	3.5
	Oat hulls	7.0	0.0	2.6	3.5

All the experimental data are given in Tables 22 and 23 in appendix B. The coefficients of digestibility are summarized in Tables 4 and 5 with the statistical analyses given in Tables 6 and 7.

From Table 4, it will be noted that the values of the coefficients of digestibility of the oat hulls for dry matter, organic matter, crude fibre and nitrogen-free extract calculated from the mixture with hay, were lower than the values for the oat hulls when fed alone. The differences were

statistically significant. In the 1 : 1 ration, which contained the larger proportion of oat hulls, the values were lower than the 5 : 3 ration for these same nutrients, but not significantly so[1].

The values for ether extract showed no change, whereas the values for nitrogen were higher in the oat hulls calculated from the mixed ration than in the oat hulls fed alone. These two nutrients constitute a very small part of the dry matter of the oat hulls.

In order to estimate the overall effect, the total digestible nutrients in percentage of dry matter are given in Table 8 with the statistical analysis in Table 9. As with the coefficients of digestibility, the total digestible nutrients of the oat hulls calculated from the mixed ration with hay were lower than the values for the oat hulls fed alone. The differences were statistically significant. These results confirm those of earlier work (11).

B. Oat Hulls-Corn Silage Combination

Following the completion of the digestion trials on corn silage previously published (13), two further periods were conducted, namely, one in which corn silage was fed with oat hulls in the ratio of 15 : 3.5 and one in which oat hulls were fed alone at a level of 7 kg. Six grade shorthorn steers were used, numbered 1 to 6. They were three years old and weighed, respectively, 486, 560, 513, 533, 540, and 544 kilograms.

The experimental data are given in appendix B in Tables 24 and 25, except those data taken from the previous paper. The results are summarized in Table 10.

It will be seen that the digestibilities of the dry matter, organic matter, nitrogen-free extract and ether extract of the hulls calculated from the oat hulls-silage ration were significantly lower than when the hulls were fed alone. The digestibility of the crude fibre did not change. However, there was a drop in nitrogen-free extract digestibility, so that total carbohydrates showed a depression in digestibility. As discussed in a previous paper on the digestibility of oat hulls (11), the values for crude fibre for this particular product cannot be given very great significance as apart from nitrogen-free extract. The digestibility of the nitrogen was enhanced by the mixture.

C. Oat Hulls-Mangels Combination

In a manner similar to the above, two periods were conducted with mangels and oat hulls following the work on mangels reported in a previous paper (12). Three grade shorthorns, numbered A, B and D, were used. They were $3\frac{1}{2}$ years old, weighing, respectively, 562, 561, and 523 kg. Complete data apart from those for the mangels are given in Tables 26 and 27 in Appendix B. A summary of the coefficients of digestibility is given in Table 11. Here again, the values for the oat hulls calculated from the mangels were noticeably lower than those when the oat hulls were fed alone. The nitrogen values were without significance because of the erratic value for the mixed ration of Animal D.

[1] In this paper, statistical significance is determined at 5% points.

TABLE 4.—COEFFICIENTS OF DIGESTIBILITY IN PER CENT OF HAY OF OAT HULLS FED ALONE AND OF HULLS CALCULATED FROM THE MIXTURES WITH HAY*

Nutrient	Period	Coefficients of digestibility				
		Hay	Oat hulls alone	Oat hulls calculated		Means
				With hay 1 : 1	With hay 3 : 5	
Dry matter	1	58.1 (III)	38.5 (IV)	33.9 (I)	29.9 (II)	40.1
	2	57.9 (I)	32.1 (II)	28.2 (III)	30.9 (IV)	37.3
	3	58.5 (IV)	37.4 (III)	28.7 (II)	32.6 (I)	39.3
	4	57.8 (II)	37.3 (I)	26.6 (IV)	34.7 (III)	39.1
	Means	58.1	36.3	29.4	32.0	38.94
Organic matter	1	59.3 (III)	40.0 (IV)	35.1 (I)	30.3 (II)	41.2
	2	59.4 (I)	33.7 (II)	29.0 (III)	31.1 (IV)	38.3
	3	60.3 (IV)	39.2 (III)	29.4 (II)	33.6 (I)	40.6
	4	59.6 (II)	39.0 (I)	27.5 (IV)	35.4 (III)	40.4
	Means	59.7	38.0	30.3	32.6	40.12
Nitrogen	1	60.4 (III)	37.8 (IV)	51.3 (I)	56.5 (II)	51.5
	2	63.0 (I)	43.8 (II)	33.2 (III)	43.5 (IV)	45.9
	3	62.6 (IV)	39.9 (III)	52.8 (II)	50.3 (I)	51.4
	4	63.5 (II)	41.5 (I)	41.0 (IV)	41.2 (III)	46.8
	Means	62.4	40.8	44.6	47.9	48.89
Ether extract	1	51.1 (III)	72.3 (IV)	64.6 (I)	58.0 (II)	61.5
	2	55.5 (I)	76.8 (II)	80.3 (III)	64.0 (IV)	69.2
	3	54.9 (IV)	69.0 (III)	81.0 (II)	85.3 (I)	72.6
	4	53.9 (II)	75.8 (I)	72.4 (IV)	86.4 (III)	72.1
	Means	53.9	73.5	74.6	73.4	68.83
Crude fibre	1	44.2 (III)	40.6 (IV)	32.0 (I)	26.9 (II)	35.9
	2	46.5 (I)	35.6 (II)	31.8 (III)	29.5 (IV)	35.9
	3	45.7 (IV)	41.3 (III)	29.0 (II)	35.9 (I)	38.0
	4	43.7 (II)	37.9 (I)	20.6 (IV)	34.7 (III)	34.2
	Means	45.0	38.9	28.4	31.8	35.99
N-free extract	1	68.8 (III)	38.6 (IV)	35.8 (I)	30.6 (II)	43.5
	2	67.1 (I)	30.7 (II)	25.5 (III)	30.0 (IV)	38.3
	3	69.4 (IV)	37.1 (III)	27.4 (II)	30.0 (I)	41.0
	4	69.5 (II)	38.5 (I)	29.7 (IV)	33.5 (III)	42.8
	Means	68.7	36.2	29.6	31.0	41.39

* Animal numbers shown by Roman numerals.

TABLE 5.—MEAN COEFFICIENTS OF DIGESTIBILITY IN PER CENT OF HAY, OF OAT HULLS FED ALONE AND OF OAT HULLS CALCULATED FROM MIXTURES WITH HAY FOR EACH ANIMAL

	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
Animal I	40.4	41.8	51.5	70.3	38.1	42.9
Animal II	37.1	38.3	54.2	67.4	33.8	39.6
Animal III	39.6	40.7	43.7	71.7	38.0	41.2
Animal IV	38.6	39.7	46.2	65.9	34.1	41.9

TABLE 6.—ANALYSIS OF VARIANCE OF COEFFICIENTS OF DIGESTIBILITY FOR HAY-OAT HULLS COMBINATION*

Nutrient	Variance due to	F	Sums of squares	Variance	$\frac{1}{2}\log_e V$	z
Dry matter	Animal	3	24.27	8.090	1.0453	0.3256
	Period	3	16.76	5.587	0.8602	0.1405
	Ration	3	2053.00	684.333	3.2642	2.5445
	Error	6	25.31	4.218	0.7197	
	Total	15	2119.34			
Organic matter	Animal	3	26.59	8.863	1.0909	0.3560
	Period	3	19.15	6.383	0.9268	0.1919
	Ration	3	2163.41	721.137	3.2904	2.5555
	Error	6	26.09	4.348	0.7349	
	Total	15	2235.24			
Nitrogen	Animal	3	276.72	92.240	2.2622	1.2761
	Period	3	105.68	35.227	1.7809	0.7948
	Ration	3	1069.41	356.470	2.9381	1.9520
	Error	6	43.12	7.187	0.9861	
	Total	15	1494.93			
Ether extract	Animal	3	84.11	28.037	1.6668	†
	Period	3	315.09	105.030	2.3271	0.1474
	Ration	3	1195.57	398.523	2.9939	0.8142
	Error	6	469.28	78.213	2.1797	
	Total	15	2064.05			
Crude fibre	Animal	3	67.44	22.480	1.5563	0.2953
	Period	3	29.04	9.680	1.1350	†
	Ration.....	3	659.25	219.750	2.6962	1.4352
	Error	6	74.72	12.453	1.2610	
	Total	15	830.45			
N-free extract	Animal	3	23.12	7.707	1.0211	0.3378
	Period	3	64.56	21.520	1.5345	0.8512
	Ration	3	4078.91	1359.637	3.6075	2.9242
	Error	6	23.53	3.922	0.6833	
	Total	15	4190.12			

* Z values have been calculated for comparisons between variance for error and variance for either animal, period or ration. For $n_1 = 3$ and $n_2 = 6$, $z = 0.7798$ and 1.1401 at P of 0.05 and 0.01, respectively.

† Variance smaller than that due to error.

TABLE 7.—NECESSARY DIFFERENCES BETWEEN TWO MEANS OF FOUR VALUES OF COEFFICIENTS OF DIGESTIBILITY FOR HAY-OAT HULLS COMBINATION

Nutrient	Necessary difference	Nutrient	Necessary difference
Dry matter	3.55	Ether extract	15.30
Organic matter	3.61	Crude fibre	6.11
Nitrogen	4.64	N-free extract	3.43

TABLE 8.—TOTAL DIGESTIBLE NUTRIENTS IN PER CENT OF DRY MATTER OF HAY, OF OAT HULLS ALONE, AND OF OAT HULLS CALCULATED FROM RATIONS WITH HAY FOR HAY-OAT HULLS COMBINATION*

Period	Hay	Oat hulls alone	Oat hulls : Hay 1 : 1	Oat hulls : Hay 3 : 5	Means
1	55.81 (III)	38.30 (IV)	34.16 (I)	29.59 (II)	39.47
2	56.40 (I)	32.60 (II)	28.16 (III)	29.81 (IV)	36 74
3	57.08 (IV)	37.69 (III)	29.01 (II)	32.79 (I)	39.14
4	56.54 (II)	37.57 (I)	26.82 (IV)	34.03 (III)	38.74
Means	56.46	36.54	29.54	31.56	38.52

* Animal numbers shown by Roman numerals.

Mean for Animal I	40.23
Mean for Animal II	36.94
Mean for Animal III	38.92
Mean for Animal IV	38.00

TABLE 9.—ANALYSIS OF VARIANCE OF VALUES OF TOTAL DIGESTIBLE NUTRIENTS FOR HAY-OAT HULLS COMBINATION*

Variance due to	F	Sums of squares	Variance	$\frac{1}{2}\log_e V$	z
Animal	3	23.4036	7.8012	1.0271	0.2942
Period	3	18.0148	6.0049	0.8963	0.1634
Ration	3	1819.3840	606.4613	3.2038	2.4709
Error	6	25.9876	4.3313	0.7329	
Total	15	1886.7900			

Necessary difference at P of 0.05 = 3.60

* Z values have been calculated for comparisons between variance for error and variance for either animal, period, or ration. For $n_1 = 3$ and $n_2 = 6$, $Z = 0.7798$ and 1.1401 at P of 0.05 and 0.01, respectively.

II. Effect of the Addition of Straw to Hay and Corn Silage

A study was made of the associative effects between hay and oat straw. At the same time advantage was taken of a subsequent experiment on corn silage to run a period at the end of the trials with a corn silage-oat straw ration. Obviously, the control over the results of the corn silage-oat straw ration could not be as definite as that in the case of the oat straw-hay ration. Four grade shorthorn animals were used, numbered 1, 2, 3, and 4, weighing, respectively, 460, 455, 460, and 445 kilograms, and all about $2\frac{1}{2}$ to 3 years in age.

Hay and oat straw were fed alone and also in the ratio of 1 : 1. The corn silage and oat straw were fed in the ratio of 14 : 2.92, the object being

TABLE 10.—COMPARISON OF COEFFICIENTS OF DIGESTIBILITY OF OAT HULLS FED ALONE AND CALCULATED FROM MIXTURES WITH CORN SILAGE*

	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
Calculated from silage—						
Animal 1	27.1	28.0	60.4	56.5	26.8	26.3
Animal 2	28.3	28.9	51.9	53.8	31.0	25.6
Animal 3	37.1	38.4	47.7	61.2	44.0	34.4
Animal 4	34.4	35.4	54.0	66.5	37.0	32.8
Animal 5	30.0	31.3	43.0	58.0	36.3	26.5
Animal 6	33.8	34.9	59.6	65.4	36.8	31.7
Mean	31.8	32.8	52.8	60.2	35.3	29.6
Standard error	±1.60	±1.66	±2.76	±2.06	±2.40	±1.57
Coeff. of variation	12.29	12.42	12.80	8.38	16.64	13.01
Fed alone—						
Animal 1	35.3	36.8	44.3	76.5	34.7	36.3
Animal 2	32.7	34.3	44.3	74.5	32.5	33.8
Animal 3	38.3	39.7	42.1	74.2	37.9	39.6
Animal 4	39.5	40.8	43.4	78.9	38.1	40.7
Animal 5	36.7	38.3	39.7	74.5	37.3	37.6
Animal 6	35.1	36.4	43.0	79.3	34.6	35.6
Mean	36.3	37.7	42.8	76.3	35.9	37.3
Standard error	±1.00	±0.97	±0.71	±0.94	±0.92	±1.05
Coeff. of variation	6.72	6.28	4.05	3.03	6.29	6.90
Difference in means	4.5	4.9	−10.0	16.1	0.6	7.7
t values	2.391	2.547	3.511	7.108		4.072

* Coefficients in per cent. t for $n = 10$ at P of 0.05 = 2.228.

TABLE 11.—COMPARISON OF COEFFICIENTS OF DIGESTIBILITY OF OAT HULLS FED ALONE AND CALCULATED FROM MIXTURE WITH MANGELS*

	Dry matter	Organic matter	Nitrogen	Crude fibre	N-free extract
Calculated from mangels—					
Animal A	28.7	30.3	52.6	22.4	29.5
Animal B	32.1	33.3	56.0	23.5	33.3
Animal D	31.1	32.6	20.6	26.8	31.9
Mean	30.6	32.1	43.1	24.2	31.6
Fed alone—					
Animal A	34.3	35.6	51.9	29.7	36.1
Animal B	34.0	35.6	50.5	30.1	35.7
Animal D	37.2	38.4	49.8	35.5	37.3
Mean	35.2	36.5	50.7	31.8	36.4
Difference between means	4.6	4.4	7.6	7.6	4.8

* Coefficients in per cent.

to have approximately the same ratio of dry matter as with the hay-oat straw ration. The feeding schedule is shown in Table 12. There were some refusals when the oat straw was fed alone but not in the mixed ration of hay and oat straw. The average daily refusals for animals 1, 2, 3 and 4 were, respectively, 0.29 kg., 0.33 kg., 0.65 kg., and 0.53 kg. They were regular throughout the trial and the composition of the refused material was similar to that of the original ration.

TABLE 12.—SCHEDULE OF EXPERIMENT FOR HAY-OAT STRAW-CORN SILAGE COMBINATION

Period	Feed	Daily rations in kilogrammes			
		Animal 1	Animal 2	Animal 3	Animal 4
1	Hay	7.5	0.0	0.0	3.0
	Oat straw	0.0	6.0	6.0	3.0
2	Hay	3.0	7.5	3.0	0.0
	Oat straw	3.0	0.0	3.0	5.5
3	Hay	0.0	3.0	7.5	7.5
	Oat straw	5.5	3.0	0.0	0.0
4	Corn silage	14.00	14.00	14.00	14.00
	Oat straw	2.92	2.92	2.92	2.92

The complete data are given in Tables 28 and 29 in appendix B. A summary of the coefficients of digestibility for the straw *(a)* fed alone, *(b)* calculated from the hay ration, and *(c)* calculated from the silage ration is given in Table 13, together with the standard errors and coefficients of variation. In order to calculate the value of the straw in the straw-silage rations, values for the silage were taken from a subsequent experiment, the data for which are not included here. In Table 14 are given the total digestible nutrients in the straw when fed alone, when calculated from a mixture with hay, and when calculated from a mixture with silage. Table 15 is an analysis of variance of the results in Table 14. From Table 13 it will be seen that the coefficients of the straw when fed alone or when calculated from the hay ration were practically the same for all the nutrients except nitrogen. In the case of this latter, the mean value for the straw calculated from the hay ration was higher than that determined in the straw when fed alone. The difference was not statistically significant.

In regard to the digestibility of oat straw fed alone and when calculated from the rations with silage, the results did not agree as well as in the case of the oat straw and hay. In the case of the dry matter, organic matter, and nitrogen-free extract, they were reasonably close. There were larger differences for the crude fibre, ether extract and nitrogen. None of the differences were, however, statistically significant. As will be explained in part III, the agreement between these two groups of figures depends considerably upon the level of feeding of silage. In a previous paper (13) it was shown that corn silage could not be used as a basal ration because there was such a large variation in its digestibility according to the level of feeding.

The data in Table 14, giving an overall picture of the general digestibility, showed no significant difference between the three sets of values.

TABLE 13.—COMPARISON OF COEFFICIENTS OF DIGESTIBILITY OF OAT STRAW WHEN FED ALONE AND WHEN CALCULATED FROM MIXTURES WITH HAY AND CORN SILAGE

	Fed alone	Calculated from hay ration	Calculated from silage ration	Fed alone	Calculated from hay ration	Calculated from silage ration
	Dry matter			Organic matter		
Animal 1	52.2	51.6	54.8	52.7	52.4	58.1
Animal 2	53.7	56.4	55.9	55.0	57.6	58.3
Animal 3	52.2	52.7	53.3	53.3	53.7	55.4
Animal 4	50.1	47.4	50.1	51.6	48.3	52.5
Mean	52.1	52.0	53.5	53.2	53.0	56.1
Standard error	±0.91	±1.85	±1.26	±0.71	±1.92	±1.36
Coefficient of variation	3.48	7.12	4.71	2.67	7.23	4.86
	Nitrogen			Ether extract		
Animal 1	30.7	36.4	37.2	50.0	50.7	37.5
Animal 2	37.6	43.7	31.6	47.0	58.1	40.0
Animal 3	35.4	37.7	32.8	41.0	44.2	38.5
Animal 4	25.1	26.8	16.0	42.0	33.3	39.0
Mean	32.2	36.2	29.4	45.0	46.6	38.8
Standard error	±2.77	±3.50	±4.63	±2.12	±5.26	±0.52
Coefficient of variation	17.20	19.33	31.47	9.43	22.56	2.69
	Crude fibre			N-free extract		
Animal 1	56.5	58.3	63.5	52.0	49.8	57.9
Animal 2	59.5	64.1	67.2	53.4	53.3	54.3
Animal 3	58.1	58.3	61.5	51.7	52.6	53.8
Animal 4	56.2	51.6	61.4	51.0	48.1	49.6
Mean	57.6	58.1	63.4	52.0	51.0	53.9
Standard error	±0.77	±2.55	±1.36	±0.50	±1.21	±1.70
Coefficient of variation	2.66	8.79	4.28	1.94	4.76	6.31

TABLE 14.—TOTAL DIGESTIBLE NUTRIENTS IN OAT STRAW WHEN FED ALONE, AND WHEN CALCULATED FROM MIXTURES WITH HAY OR SILAGE*

	Fed alone	Calculated from mixture with hay	Calculated from mixture with silage
Animal 1	50.00	50.04	54.74
Animal 2	51.90	54.72	54.48
Animal 3	50.07	50.88	52.01
Animal 4	48.60	44.99	49.33
Mean	50.14	50.16	52.64
Standard error	±0.68	±2.00	±1.26
Coefficient of variation	2.70	7.98	4.80

* In per cent of dry matter.

TABLE 15.—ANALYSIS OF VARIANCE OF TOTAL DIGESTIBLE NUTRIENTS IN OAT STRAW*

Variance	F	Sums of squares	Variance	$\frac{1}{2}\log_e V$	z
Between	2	16.5344	8.2672	1.0561	0.0116
Within	9	72.6976	8.0775	1.0445	

* For $n_1 = 2$, and $n_2 = 9$, $z = 0.7242$ at P of 0.05.

III. Effect of the Addition of Hay to Silage and Mangels

A. Hay-Corn Silage Combination

In studying combinations of hay and corn silage, three rations in three consecutive periods were fed to four grade shorthorn steers, designated A, B, C, and D. The animals were $2\frac{1}{2}$ years old and weighed respectively 419, 442, 424, and 469 in kilogrammes. In Period I, hay was fed at a level of 7.25 kilogrammes per animal per day. In Period 2, animals A and B received a ration of 5 kilogrammes of hay and 15 kilogrammes of corn silage, while animals C and D received 5 kilogrammes of hay and 20 kilogrammes of corn silage. In the third Period all animals received 25 kilogrammes of corn silage.

The complete data are given in Tables 30 and 31 in Appendix B, and a summary of the coefficients of digestibility is given in Table 16. The total digestible nutrients for the silage when fed alone and the silage when calculated from rations with hay are given in Table 17.

From Table 16 it will be seen that the values for the silage determined alone or calculated from a ration with hay were similar except in the case

TABLE 16.—COEFFICIENTS OF DIGESTIBILITY OF SILAGE FED ALONE AND CALCULATED FROM A RATION WITH HAY*

	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
Silage alone—						
Animal A	68.2	69.5	55.4	77.1	62.6	73.9
Animal B	69.5	71.3	57.0	76.4	67.4	74.6
Animal C	65.8	67.7	53.7	76.3	61.3	71.9
Animal D	66.5	68.1	54.5	75.6	61.4	72.4
Mean	67.5	69.2	55.2	76.4	63.2	73.2
Standard error	±0.84	±0.81	±0.71	±0.31	±1.44	±0.63
Coefficient of variation	2.48	2.35	2.57	0.81	4.55	1.72
Silage fed with hay—						
Animal A	73.5	73.9	53.0	79.5	79.1	74.6
Animal B	68.7	69.9	51.0	75.8	70.6	73.4
Animal C	65.1	66.6	43.5	78.1	65.0	70.4
Animal D	64.8	65.8	47.9	82.4	60.2	70.5
Mean	68.0	69.1	48.9	79.0	68.7	72.2
Standard error	±2.03	±1.85	±2.07	±1.38	±4.06	±1.05
Coefficient of variation	5.70	5.34	8.47	3.49	11.81	2.92

* Coefficients in per cent.

TABLE 17.—TOTAL DIGESTIBLE NUTRIENTS IN CORN SILAGE WHEN FED ALONE AND WITH HAY*

	Silage fed alone	Silage calculated from ration with hay
Animal A	68.02	72.64
Animal B	69.77	69.36
Animal C	66.36	66.08
Animal D	66.69	65.17
Mean	67.71	68.31
Standard error	±0.77	±1.70
Coefficient of variation	2.29	4.98

* Results in per cent of dry matter.

of the nitrogen and the crude fibre. In the case of the crude fibre the difference was not statistically significant. In the case of the nitrogen the coefficient of digestibility when the silage was fed alone was higher than when it was calculated from the hay silage ration. The total digestible nutrients on a dry matter basis were the same whether the silage was fed alone or calculated from a ration with hay.

In a previous paper (13), it was shown that with corn silage, as the level of feeding increased, the digestibility decreased. Therefore, in attempting to determine any associative effects in which corn silage constitutes one of the component feeds, the results will be dependent to a certain extent upon the level of feeding. The oat straw experiment referred to above in Part II, as well as this present experiment, was completed before the work with corn silage was available. The agreement between the coefficients of digestibility of corn silage fed alone and those calculated from rations with either straw or hay must, therefore, be considered to a certain extent fortuitous. Nevertheless, when the data recently published on corn silage (13) are combined with these present data, certain inferences can be drawn. In experiment 3 in that paper, data were given for silage when fed alone at a level of 22 kilogrammes per animal per day, and for silage added in different amounts to a constant ration of hay. A summary of some of the data is given in Table 18. The first column gives the mean

TABLE 18.—COMPARISON OF MEAN COEFFICIENTS OF DIGESTIBILITY OF CORN SILAGE WHEN FED ALONE AND WHEN CALCULATED FROM MIXED RATIONS WITH HAY*

Nutrient	Coefficients of digestibility			
	Silage fed alone (22 kilos)	Means of all calculated values for corn silage	Silage at 22 kilo level with hay	Silage at 16 kilo level with hay
Dry matter	67.3	67.9	65.1	67.3
Organic matter	69.5	70.5	67.6	69.8
Nitrogen	54.8	47.2	46.7	46.3
Ether extract	71.6	72.2	71.5	71.2
Crude fibre	64.8	69.0	62.1	67.5
N-free extract	73.8	74.0	72.4	73.6

* Coefficients in per cent.

coefficients of digestibility of corn silage when fed alone. The second column gives the mean of all the values of corn silage calculated from the hay-corn silage rations. In the third column are given the mean values for silage calculated from that ration in which the silage was fed at the same level as when fed alone. In the fourth column are given the mean values for silage calculated from that ration in which the silage was fed at the next lower level to the above. It will be observed that with the exception of nitrogen and crude fibre, the values in columns one, two, and four are very similar. The lowering of the digestibility of nitrogen in the mixed ration was the same as found in a previous experiment. The differences in the crude fibre values were not statistically significant. The values in column three, with the exception of the ether extract, were slightly lower than those in column one. Nitrogen, as in the other cases, showed a depression in digestibility. The differences in these two columns, 1 and 3, with the exception of the nitrogen, were not statistically significant.

A second method of comparing silage when fed alone or silage when fed as a mixed ration is to follow the change in digestibility with increasing plane. In the paper under discussion (13) Experiments 1 and 3, namely, silage fed alone at varying levels and silage fed at varying levels with a constant ration of hay, were conducted in different years. Nevertheless, the conditions surrounding both experiments were very similar. The animals were of the same age, $3\frac{1}{2}$ years, and of the same average weight, 548 and 550 kilogrammes, respectively. Moreover, the range of feeding of the silage alone was practically the same as that for the silage with the hay. Further, the coefficients of digestibility of the silage for the two years were, in general, similar. In the third experiment of that paper, in which silage was added to hay, a determination was made of the digestibility of the silage alone. It was fed at a level of 22 kilogrammes per animal per day. The level of silage approaching this in the first experiment was 20 kilogrammes. The mean coefficients of digestibility in both these cases have been compared in Table 19. In the cases of ether extract and crude fibre, the differences were statistically significant. In the cases of dry matter, organic matter, and nitrogen-free extract, there were no significant

TABLE 19.—MEAN COEFFICIENTS OF DIGESTIBILITY OF CORN SILAGE IN FIRST AND THIRD EXPERIMENTS OF PREVIOUS PAPER*

Nutrient	Coefficients of digestibility		Difference in coefficients	t values
	Silage from first experiment (20 kilos —Means of 6 values each)	Silage from third experiment (22 kilos —Means of 4 values each)		
Dry matter	65.9	67.3	1.4	1.407
Organic matter	68.6	69.5	0.9	1.071
Nitrogen	52.3	54.8	2.5	0.880
Ether extract	78.1	71.6	6.5	3.169
Crude fibre	61.2	64.8	3.6	2.406
N-free extract	73.2	73.8	0.6	0.627

* Coefficients in per cent; $t = 2.306$ at P of 0.05.

differences. Ether extract is of almost negligible importance in corn silage. The difference in the case of the crude fibre was not of too great a magnitude, particularly when its standard error was ± 1.50.

For the dry matter, organic matter, crude fibre, and nitrogen-free extract in both experiments, the quantities consumed were plotted on abscissae and the quantities digested on ordinates. Curves of the second degree, passing through the origin were fitted to the points, resulting in the equations as given in Table 20.

TABLE 20.—SECOND DEGREE EQUATIONS FOR GRAPHS OF DIGESTED AGAINST CONSUMED NUTRIENTS IN SILAGE FED ALONE AND SILAGE CALCULATED FROM MIXTURES WITH HAY*

Nutrient	Equations of second degree			
	Silage, fed alone 16 values $Y =$	Silage calculated from mixtures with hay, 20 values $Y =$	t for first degree co-efficient $n = 32$	t for second degree co-efficient $n = 32$
Dry matter	$0.727x - 0.0014x^2$	$0.716x - 0.0009x^2$	0.525	1.279
Organic matter	$0.751x - 0.0014x^2$	$0.746x - 0.0011x^2$	0.204	0.779
Crude fibre	$0.718x - 0.0074x^2$	$0.751x - 0.0063x^2$	0.638	3.583
N-free extract	$0.780x - 0.0017x^2$	$0.772x - 0.0013x^2$	0.354	1.592

* Y = amount digested, x = amount consumed. Necessary t at P of 0.05 = 2.04.

D. B. DeLury, of the University of Toronto, kindly suggested the method for determining whether or not the two sets of equations were significantly different. The method is given in Appendix A. From the t values given in the table for the coefficients of the first and second degree, it will be seen that only in the case of the coefficient of the second degree of crude fibre was there any significant difference.

In view, therefore, of the data presented in Tables 16 and 17, supplemented by the data presented in Tables 18, 19 and 20, the authors draw the conclusion that there was no associative effect between corn silage and hay. This conclusion is modified by the stipulation that the operation of the plane factor may change the digestibility of corn silage in a mixed roughage ration as compared with any given value.

EXPERIMENT 6—*Hay-Mangels*

In a previous paper, the effect of the plane of nutrition upon mangels was studied in which mangels were fed with a constant ration of hay.

TABLE 21.—COMPARISON OF COEFFICIENTS OF DIGESTIBILITY—MANGELS FED ALONE AND CALCULATED FROM MIXTURES WITH HAY*

Nutrient	Coefficient of digestibility	
	Fed alone (Means of 8 values)	Calculated from mixtures with hay (Means of 28 values)
Dry matter	86.1	85.2
Organic matter	87.8	87.1
Nitrogen	74.2	70.9
N-free extract	95.0	94.1

* Coefficients in per cent.

The data in that paper can be used to study the associative effect of these two feeds. In Table 21 is given a summary of the coefficients of digestibility of mangels when fed alone and of mangels when calculated from the rations with hay. There was no significant difference in digestibility.

SUMMARY

Using grade Shorthorn steers as experimental animals, studies were made of associative digestibility among dry and succulent roughages. As typical feeds in these classes, mixed hay, oat straw, oat hulls, corn silage, and mangels were chosen.

The method of procedure was to determine the coefficients of digestibility of *(a)* these feeds when fed as the sole ration, *(b)* rations made up of combinations of various pairs of these feeds. The digestibility of one of the individual components in each mixed ration was then compared with its digestibility when fed alone.

From the data presented in this paper, it was concluded that among hay, oat straw, corn silage and mangels there was no associative effect as far as total digestibility and total digestible nutrients were concerned. Due to the effect of the plane of nutrition, however, the digestibility of the corn silage in a mixed roughage ration would vary inversely as the quantities consumed.

It was further concluded that the digestibility of oat hulls, calculated from a mixed ration with either hay, corn silage, or mangels, was lower than the digestibility observed when oat hulls constituted the sole ration.

The digestibility of the nitrogen did not generally follow the trend of total digestibility. In the case of the additions of hay to silage or mangels the digestibility of the nitrogen tended to decrease, whereas in the case of the addition of hulls to hay or silage, the digestibility of the nitrogen in the mixed ration tended to increase.

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APPENDIX A

A Test for Significant Difference between Corresponding Coefficients of Two Regression Lines

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Let

$$y_\alpha, x_{1\alpha}, x_{2\alpha}, \ldots\ldots x_{p\alpha}, \qquad (\alpha = 1, 2, \ldots N)$$

and

$$y^1_\beta, x^1_{1\beta}, x^1_{2\beta}, \ldots\ldots x^1_{p\beta}, \qquad (\beta = 1, 2, \ldots N^1)$$

be two independent sets of observations on the variates $y, x_1, x_2, \ldots\ldots x_p$. To each set we fit a regression line,

$$Y = b_1x_1 + b_2x_2 + \ldots\ldots + b_px_p;$$
$$Y^1 = b^1_1x_1 + b^1_2x_2 + \ldots\ldots + b^1_px_p.$$

If, in the population sampled, y is normally distributed, for every given set of x values, with constant variance σ^2, then the differences $b_i - b^1_i$, $(i = 1, 2, \ldots p)$ are normally distributed with zero mean and variance $\sigma^2(c_{ii} + c^1_{ii})$, where the numbers c_{ii} and c^1_{ii} are defined as follows. Let $a_{ij}(i, j = 1, 2, \ldots p)$ be the coefficients of the normal equations, computed from the first sample, $a_{ij} = \sum_{\alpha=1}^{N} x_{i\alpha}x_{j\alpha}$, and let D be the determinant of these coefficients, $D = |a_{ij}|$. Then c_{ij} is the cofactor of a_{ij} in D, divided by D. In the same way, c^1_{ij} is calculated from the second sample.

The optimum estimate of the variance σ^2 is

$$s^2 = \frac{1}{N + N^1 - 2p}\left[\sum_{\alpha=1}^{N}(Y_\alpha - y_\alpha)^2 + \sum_{\beta=1}^{N^1}(Y^1_\beta - y^1_\beta)^2\right]$$

when $Y_\alpha = b_1x_{1\alpha} + b_2x_{2\alpha} + \ldots\ldots + b_px_{p\alpha}$, etc. and $t = \dfrac{b_i - b^1_i}{s\sqrt{c_{ii} + c^1_{ii}}}$ is distributed in Fisher's t-distribution with $N + N^1 - 2p$ degrees of freedom.

In the foregoing article, this test is used with $p = 2$, and $x_2 = x^2_1 = x^2$. The explicit formulae for this case are:

$$D = (\Sigma x^2_\alpha)(\Sigma x^4_\alpha) - (\Sigma x^3_\alpha)^2$$

$$c_{11} = \frac{\Sigma x^4_\alpha}{D}$$

$$c_{22} = \frac{\Sigma x^2_\alpha}{D}$$

APPENDIX B

TABLE 22.—CHEMICAL COMPOSITION IN PER CENT OF FEEDING STUFFS FOR HAY-OAT HULLS COMBINATION

Feed	Period	Moisture	On dry matter basis				
			Ash	Protein*	Ether extract	Crude fibre	N-free extract
Hay	1 and 2	12.96	7.36	13.92	2.29	32.54	43.89
Hay	3 and 4	12.51	7.05	14.08	2.43	32.08	44.36
Oat hulls	1 and 2	6.43	6.39	3.60	1.20	33.64	55.17
Oat hulls	3	7.22	6.37	3.78	1.15	33.73	54.97
Oat hulls	4	7.19	6.34	3.67	1.32	32.80	55.87

* N × 6.25.

TABLE 23.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY FOR HAY-OAT HULLS COMBINATION

(Collection period of 12 days; weights in kilogrammes; coefficients in per cent.)

	Original Weights	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
			Period 1				
Animal C							
In hay	42.000	36.557	33.866	0.814	0.837	11.896	16.045
In hulls	42.000	39.299	36.788	0.226	0.472	13.220	21.681
Total	84.000	75.856	70.654	1.040	1.309	25.116	37.726
In feces	156.680	41.281	37.508	0.416	0.553	15.534	18.948
Digested		34.575	33.146	0.624	0.756	9.582	18.778
Coefficient		45.6	46.9	60.0	57.8	38.2	49.8
Dig. from hay		21.240	20.218	0.508	0.451	5.353	11.023
Dig. from hulls		13.335	12.928	0.116	0.305	4.229	7.755
Coefficient		33.9	35.1	51.3	64.6	32.0	35.8
Animal E							
In hay	52.800	45.957	42.575	1.023	1.052	14.954	20.171
In hulls	31.200	29.194	27.329	0.168	0.350	9.821	16.106
Total	84.000	75.151	69.904	1.191	1.402	24.775	36.277
In feces	149.222	39.723	36.196	0.458	0.632	15.401	17.486
Digested		35.428	33.708	0.733	0.770	9.374	18.791
Coefficient		47.1	48.2	61.5	54.9	37.8	51.8
Dig. from hay		26.701	25.417	0.638	0.567	6.729	13.857
Dig. from hulls		8.727	8.291	0.095	0.203	2.645	4.934
Coefficient		29.9	30.3	56.5	58.0	26.9	30.6
Animal F							
In hay	84.000	73.114	67.733	1.628	1.674	23.791	32.090
In feces	226.052	30.666	27.541	0.644	0.819	13.278	10.009
Digested		42.448	40.192	0.984	0.855	10.513	22.081
Coefficient		58.1	59.3	60.4	51.1	44.2	68.8
Animal G							
In hulls	84.000	78.599	73.577	0.452	0.943	26.441	43.363
In feces	152.534	48.353	44.141	0.281	0.261	15.715	26.638
Digested		30.246	29.436	0.171	0.682	10.726	16.725
Coefficient		38.5	40.0	37.8	72.3	40.6	38.6

TABLE 23.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY FOR HAY-OAT HULLS COMBINATION—*Continued*

(Collection period of 12 days; weights in kilogrammes; coefficients in per cent.)

	Original weights	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
			Period 2				
Animal C							
In hay	84.000	73.114	67.733	1.628	1.674	23.791	32.090
In feces	185.369	30.801	27.515	0.602	0.745	12.736	10.568
Digested		42.313	40.218	1.026	0.929	11.055	21.522
Coefficient		57.9	59.4	63.0	55.5	46.5	67.1
Animal E							
In hulls	84.000	78.599	73.577	0.452	0.943	26.441	43.363
In feces	134.548	53.378	48.761	0.254	0.219	17.017	30.030
Digested		25.221	24.816	0.198	0.724	9.424	13.333
Coefficient		32.1	33.7	43.8	76.8	35.6	30.7
Animal F							
In hay	42.000	36.557	33.866	0.814	0.837	11.896	16.045
In hulls	42.000	39.299	36.788	0.226	0.472	13.220	21.681
Total	84.000	75.856	70.654	1.040	1.309	25.116	37.726
In feces	190.010	43.524	39.759	0.457	0.479	15.560	21.170
Digested		32.332	30.895	0.583	0.830	9.556	16.556
Coefficient		42.6	43.7	56.1	63.4	38.0	43.9
Dig. from hay		21.240	20.218	0.508	0.451	5.353	11.023
Dig. from hulls		11.092	10.677	0.075	0.379	4.203	5.533
Coeff. of hulls		28.2	29.0	33.2	80.3	31.8	25.5
Animal G							
In hay	52.800	45.957	42.575	1.023	1.052	14.954	20.171
In hulls	31.200	29.194	27.329	0.168	0.350	9.821	16.106
In total	84.000	75.151	69.904	1.191	1.402	24.775	36.277
In feces	189.331	39.432	35.982	0.480	0.611	15.146	17.591
Digested		35.719	33.922	0.711	0.791	9.629	18.686
Coefficient		47.5	48.5	59.7	56.4	38.9	51.5
Dig. from hay		26.701	25.417	0.638	0.567	6.729	13.857
Dig. from hulls		9.018	8.505	0.073	0.224	2.900	4.829
Coeff. of hulls		30.9	31.1	43.5	64.0	29.5	30.0
			Period 3				
Animal C							
In hay	52.800	46.195	42.938	1.040	1.123	14.819	20.492
In oat hulls	31.200	28.947	27.103	0.175	0.333	9.764	15.912
Total	84.000	75.142	70.041	1.215	1.456	24.583	36.404
In feces	155.533	38.860	35.308	0.478	0.567	14.409	17.545
Digested		36.282	34.733	0.737	0.889	10.174	18.859
Coefficient		48.3	49.6	60.7	61.1	41.4	51.8
Dig. from hay		26.839	25.634	0.649	0.605	6.669	14.078
Dig. from hulls		9.443	9.099	0.088	0.284	3.505	4.781
Coeff. of hulls		32.6	33.6	50.3	85.3	35.9	30.0
Animal E							
In hay	42.000	36.746	34.155	0.827	0.893	11.788	16.301
In hulls	42.000	38.968	36.486	0.235	0.448	13.144	21.421
Total	84.000	75.714	70.641	1.062	1.341	24.932	37.722
In feces	144.950	43.191	39.507	0.422	0.497	15.812	20.663
Digested		32.523	31.134	0.640	0.844	9.120	17.059
Coefficient		43.0	44.1	60.3	62.9	36.6	45.2
Dig. from hay		21.349	20.391	0.516	0.481	5.305	11.199
Dig. from hulls		11.174	10.743	0.124	0.363	3.815	5.860
Coeff. of hulls		28.7	29.4	52.8	81.0	29.0	27.4

TABLE 23.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY FOR HAY-OAT HULLS COMBINATION—*Concluded*

(Collection period of 12 days; weights in kilogrammes; coefficients in per cent.)

	Original weights	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
			Period 3—Concluded				
Animal F							
In oat hulls	84.000	77.935	72.971	0.471	0.896	26.287	42.841
In feces	153.937	48.766	44.392	0.283	0.278	15.420	26.953
Digested		29.169	28.579	0.188	0.618	10.867	15.888
Coefficient		37.4	39.2	39.9	69.0	41.3	37.1
Animal G							
In hay	84.000	73.492	68.311	1.654	1.786	23.576	32.601
In feces	172.179	30.522	27.100	0.618	0.806	12.801	9.965
Digested		42.970	41.211	1.036	0.980	10.775	22.636
Coefficient		58.5	60.3	62.6	54.9	45.7	69.4
			Period 4				
Animal C							
In oat hulls	84.000	77.960	73.017	0.458	1.029	25.571	43.556
In feces	141.897	48.897	44.570	0.268	0.249	15.877	26.805
Digested		29.063	28.447	0.190	0.780	9.694	16.751
Coefficient		37.3	39.0	41.5	75.8	37.9	38.5
Animal E							
In hay	84.000	73.492	68.311	1.654	1.786	23.576	32.601
In feces	167.581	30.996	27.571	0.604	0.824	13.285	9.947
Digested		42.496	40.740	1.050	0.962	10.291	22.654
Coefficient		57.8	59.6	63.5	53.9	43.7	69.5
Animal F							
In hay	52.800	46.195	42.938	1.040	1.123	14.819	20.492
In oat hulls	31.200	28.957	27.121	0.170	0.382	9.498	16.178
Total	84.000	75.152	70.059	1.210	1.505	24.317	36.670
In feces	165.717	38.275	34.815	0.491	0.570	14.349	17.170
Digested		36.877	35.244	0.719	0.935	9.968	19.500
Coefficient		49.1	50.3	59.4	62.1	41.0	53.2
Dig. from hay		26.839	25.634	0.649	0.605	6.669	14.078
Dig. from hulls		10.038	9.610	0.070	0.330	3.299	5.422
Coeff. of hulls		34.7	35.4	41.2	86.4	34.7	33.5
Animal G							
In hay	42.000	36.746	34.155	0.827	0.893	11.788	16.301
In hulls	42.000	38.980	36.509	0.229	0.515	12.785	21.778
Total	84.000	75.726	70.664	1.056	1.408	24.573	38.079
In feces	164.242	44.004	40.228	0.446	0.554	16.634	20.422
Digested		31.722	30.436	0.610	0.854	7.939	17.657
Coefficient		41.9	43.1	57.8	60.7	32.3	46.4
Dig. from hay		21.349	20.391	0.516	0.481	5.305	11.199
Dig. from hulls		10.373	10.045	0.094	0.373	2.634	6.458
Coeff. of hulls		26.6	27.5	41.0	72.4	20.6	29.7

TABLE 24.—CHEMICAL COMPOSITION IN PER CENT OF FEEDING STUFFS FOR SILAGE-OAT HULLS COMBINATION

Feed	Period	Moisture	On dry matter basis				
			Ash	Protein*	Ether extract	Crude fibre	N-free extract
Oat hulls	1	7.22	6.37	3.78	1.15	33.73	54.97
Oat hulls	2	7.19	6.34	3.67	1.32	32.80	55.87
Corn silage†	1	80.31	4.80	9.29	2.72	31.60	51.59

* N × 6.25.
† N in original material = 0.314%.

TABLE 25.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY FOR SILAGE-OAT HULLS COMBINATION

(Collection period of 12 days; weights in kilogrammes; coefficients in per cent.)

	Original weight	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
Period 1							
Consumed (all animals)							
In silage	180.000	35.442	33.741	0.527	0.964	11.200	18.285
In oat hulls	42.000	38.968	36.486	0.235	0.448	13.144	21.421
Total	222.000	74.410	70.227	0.762	1.412	24.344	39.706
Dig. from silage		22.896	22.438	0.281	0.782	6.933	12.708
In feces							
Animal 1	135.491	40.972	37.584	0.339	0.377	13.885	21.371
2	159.450	40.487	37.260	0.359	0.389	13.332	21.511
3	124.491	37.073	33.796	0.369	0.356	11.630	19.638
4	148.573	38.106	34.871	0.354	0.332	12.544	19.971
5	153.974	39.837	36.387	0.380	0.370	12.640	21.321
6	131.068	38.333	35.071	0.341	0.337	12.573	20.209
Digested							
Animal 1		33.438	32.643	0.423	1.035	10.459	18.335
2		33.923	32.967	0.403	1.023	11.012	18.195
3		37.337	36.431	0.393	1.056	12.714	20.068
4		36.304	35.356	0.408	1.080	11.800	19.735
5		34.573	33.840	0.382	1.042	11.704	18.385
6		36.077	35.156	0.421	1.075	11.771	19.497
Digested from oat hulls							
Animal 1		10.542	10.205	0.142	0.253	3.526	5.627
2		11.027	10.529	0.122	0.241	4.079	5.487
3		14.441	13.993	0.112	0.274	5.781	7.360
4		13.408	12.918	0.127	0.298	4.867	7.027
5		11.677	11.402	0.101	0.260	4.771	5.677
6		13.181	12.718	0.140	0.293	4.838	6.789
Coeff. of oat hulls							
Animal 1		27.1	28.0	60.4	56.5	26.8	26.3
2		28.3	28.9	51.9	53.8	31.0	25.6
3		37.1	38.4	47.7	61.2	44.0	34.4
4		34.4	35.4	54.0	66.5	37.0	32.8
5		30.0	31.3	43.0	58.0	36.3	26.5
6		33.8	34.9	59.6	65.4	36.8	31.7

TABLE 25.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY FOR SILAGE-OAT HULLS COMBINATION—*Concluded*

(Collection period of 12 days; weights in kilogrammes; coefficients in per cent.)

	Original weight	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
			Period 2				
In oat hulls							
(All animals)	84.000	77.960	73.017	0.458	1.029	25.571	43.556
In Feces							
Animal 1	130.247	50.441	46.138	0.255	0.242	16.701	27.738
2	143.624	52.431	47.948	0.255	0.262	17.271	28.842
3	133.626	48.104	44.030	0.265	0.265	15.879	26.318
4	132.492	47.182	43.261	0.259	0.217	15.820	25.837
5	139.679	49.368	45.019	0.276	0.262	16.045	27.187
6	130.524	50.633	46.461	0.261	0.213	16.714	28.071
Digested							
Animal 1		27.519	26.879	0.203	0.787	8.870	15.818
2		25.529	25.069	0.203	0.767	8.300	14.714
3		29.856	28.987	0.193	0.764	9.692	17.238
4		30.778	29.756	0.199	0.812	9.751	17.719
5		28.592	27.998	0.182	0.767	9.526	16.369
6		27.327	26.556	0.197	0.816	8.857	15.485
Coefficients							
Animal 1		35.3	36.8	44.3	76.5	34.7	36.3
2		32.7	34.3	44.3	74.5	32.5	33.8
3		38.3	39.7	42.1	74.2	37.9	39.6
4		39.5	40.8	43.4	78.9	38.1	40 7
5		36.7	38.3	39.7	74.5	37.3	37.6
6		35.1	36.4	43.0	79.3	34.6	35.6

TABLE 26.—CHEMICAL COMPOSITION IN PER CENT OF FEEDING STUFFS FOR MANGELS-OAT HULLS COMBINATION

Feed	Period	Moisture	On dry matter basis				
			Ash	Protein*	Ether extract	Crude fibre	N-free extract
Oat hulls	1 and 2	90.79	5.97	4.77	1.43	31.46	56.37
Mangels†	1	89.09	9.64	9.15	0.73	7.60	72.88

* N × 6.25.

† N in original material = 0.203%

TABLE 27.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY FOR MANGELS-OAT HULLS COMBINATION

(Collection period of 12 days; weights in kilogrammes; coefficients in per cent.)

	Original weight	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
			Period 1				
All animals							
In mangels	360.000	39.276	35.490	0.729	0.287	2.985	28.624
In oat hulls	42.000	38.132	35.856	0.291	0.545	11.996	21.945
Total	402.000	77.408	71.346	1.020	0.832	14.981	50.119

TABLE 27.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY FOR MANGELS-OAT HULLS COMBINATION—*Concluded*

(Collection period of 12 days; weights in kilogrammes; coefficients in per cent)

	Original weight	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
Animal A							
In feces	105.929	32.664	29.352	0.326	0.376	10.691	16.577
Digested		44.744	41.994	0.694	0.456	4.290	33.542
Digested from mangels		33.817	31.125	0.541		1.597	27.193
Digested from hulls		10.927	10.869	0.153		2.693	6.349
Coeff. of hulls		28.7	30.3	52.6		22.4	29.5
Animal B							
In feces	100.153	31.355	28.273	0.316	0.342	10.560	15.778
Digested		46.053	43.073	0.704	0.490	4.421	34.341
Digested from mangels		33.817	31.125	0.541		1.597	27.193
Digested from hulls		12.236	11.948	0.163		2.824	7.148
Coeff. of hulls		32.1	33.3	56.0		23.5	33.3
Animal D							
In feces	127.084	31.747	28.544	0.419	0.352	10.175	16.067
Digested		45.661	42.802	0.601	0.480	4.806	34.052
Digested from mangels		33.817	31.125	0.541		1.597	27.193
Digested from hulls		11.844	11.677	0.060		3.209	6.859
Coeff. of hulls		31.1	32.6	20.6		26.8	31.9
Period 2							
Intake for all animals							
Oat hulls	84.000	76.264	71.711	0.582	1.091	23.993	42.990
In feces							
Animal A	133.279	50.131	46.166	0.280	0.311	16.874	27.492
Animal B	139.578	50.301	46.156	0.288	0.322	16.760	27.645
Animal D	131.188	47.916	44.183	0.292	0.278	15.486	26.967
Digested							
Animal A		26.133	25.545	0.302	0.780	7.119	15.498
Animal B		25.963	25.555	0.294	0.769	7.233	15.345
Animal D		28.348	27.528	0.280	0.813	8.507	16.023
Coefficients							
Animal A		34.3	35.6	51.9	71.5	29.7	36.1
Animal B		34.0	35.6	50.5	70.5	30.1	35.7
Animal D		37.2	38.4	49.8	74.5	35.5	37.3

TABLE 28.—CHEMICAL COMPOSITION IN PER CENT OF FEEDING STUFFS FOR HAY-STRAW SILAGE COMBINATION

Feed	Period	Moisture	On dry matter basis				
			Ash	Protein*	Ether extract	Crude fibre	N-free extract
Oat straw	1	9.33	9.32	4.97	3.31	37.94	44.46
	2	9.21	8.57	4.82	3.17	39.07	44.37
	3	9.09	8.81	4.71	3.19	38.90	44.39
	4	10.08	9.02	4.79	3.11	38.47	44.61
Hay	1	9.09	7.91	11.97	2.76	29.23	48.13
	2	8.40	7.87	12.33	2.85	29.63	47.32
	3	8.85	8.36	12.77	3.01	29.38	46.48
Corn silage	4	81.19	5.00	7.92	2.45	33.55	51.08

* N × 6.25.

TABLE 29.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY FOR HAY-STRAW-SILAGE COMBINATION

(Collection period of 12 days; weights in kilogrammes; coefficients in per cent.)

	Original weights	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
			Period 1				
Animal 1							
In hay	90.00	81.819	75.348	1.566	2.259	23.913	39.384
In feces	172.65	30.678	27.423	0.618	0.886	13.269	9.590
Digested		51.141	47.925	0.948	1.373	10.644	29.794
Coefficient		62.5	63.6	60.5	60.8	44.5	75.7
Animal 2							
In straw	72.000	65.282	59.393	0.500	2.030	25.114	29.124
Refused	4.219	4.058	3.733	0.026	0.091	1.659	1.824
Consumed	67.781	61.224	55.660	0.474	1.939	23.455	27.300
In feces	178.76	28.339	25.029	0.296	1.028	9.499	12.728
Digested		32.885	30.631	0.178	0.911	13.956	14.572
Coefficient		53.7	55.0	37.6	47.0	59.5	53.4
Animal 3							
In straw	72.000	65.282	59.393	0.500	2.030	25.114	29.124
Refused	7.781	7.379	6.754	0.043	0.129	3.015	3.345
Consumed	64.219	57.903	52.639	0.457	1.901	22.099	25.779
In feces	146.68	27.693	24.578	0.295	1.122	9.262	12.452
Digested		30.210	28.061	0.162	0.779	12.837	13.327
Coefficient		52.2	53.3	35.4	41.0	58.1	51.7
Animal 4							
In hay	36.00	32.728	30.139	0.626	0.904	9.565	15.754
In straw	36.00	32.641	29.696	0.250	1.015	12.557	14.562
Total	72.00	65.369	59.835	0.876	1.919	22.122	30.316
In feces	173.78	29.629	26.459	0.432	1.014	11.392	11.507
Digested		35.740	33.376	0.444	0.905	10.730	18.809
Coefficient		54.7	55.8	50.7	47.2	48.5	62.0
Dig. from hay		20.259	19.018	0.377	0.567	4.256	11.800
Dig. from straw		15.481	14.358	0.067	0.338	6.474	7.009
Coeff. of straw		47.4	48.3	26.8	33.3	51.6	48.1
			Period 2				
Animal 1							
In hay	36.000	32.976	30.380	0.650	0.940	9.770	15.606
In straw	36.000	32.684	29.804	0.247	1.044	12.715	14.504
Total	72.000	65.660	60.184	0.897	1.984	22.485	30.110
In feces	153.017	28.397	25.388	0.415	0.866	10.723	11.196
Digested		37.263	34.796	0.482	1.118	11.762	18.914
Coefficient		56.8	57.8	53.7	56.4	52.3	62.8
Dig. from hay		20.412	19.170	0.392	0.589	4.348	11.689
Dig. from straw		16.851	15.626	0.090	0.529	7.414	7.225
Coeff. of straw		51.6	52.4	36.4	50.7	58.3	49.8
Animal 2							
In hay	90.000	82.440	75.951	1.626	2.349	24.426	39.015
In feces	182.961	31.233	27.820	0.647	0.808	13.408	9.726
Digested		51.207	48.131	0.979	1.541	11.018	29.289
Coefficient		62.1	63.4	60.2	65.6	45.1	75.1

TABLE 29.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY FOR HAY-STRAW-SILAGE COMBINATION—*Continued*

(Collection period of 12 days; weights in kilogrammes; coefficients in per cent.)

	Original weights	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
			Period 2—Concluded				
Animal 3							
In hay	36.000	32.976	30.380	0.650	0.940	9.770	15.606
In straw	36.000	32.684	29.804	0.247	1.044	12.715	14.504
Total	72.000	65.660	60.184	0.897	1.984	22.485	30.110
In feces	150.260	28.030	25.015	0.412	0.934	10.727	10.799
Digested		37.630	35.169	0.485	1.050	11.758	19.311
Coefficient		57.3	58.4	54.1	52.9	52.3	64.1
Dig. from hay		20.412	19.170	0.392	0.589	4.348	11.689
Dig. from straw		17.218	15.999	0.093	0.461	7.410	7.622
Coeff. of straw		52.7	53.7	37.7	44.2	58.3	52.6
Animal 4							
In straw	66.000	59.921	54.641	0.452	1.914	23.311	26.591
Refused	6.296	5.940	5.441	0.038	0.131	2.496	2.578
Consumed	59.704	53.981	49.200	0.414	1.783	20.815	24.013
In feces	153.435	26.933	23.815	0.310	1.035	9.123	11.766
Digested		27.048	25.385	0.104	0.748	11.692	12.247
Coefficient		50.1	51.6	25.1	42.0	56.2	51.0
			Period 3				
Animal 1							
In straw	66.000	60.001	54.859	0.462	1.901	23.443	26.624
Refused	3.500	3.354	2.993	0.025	0.079	1.257	1.499
Consumed	62.500	56.647	51.866	0.437	1.822	22.186	25.125
In feces	157.418	27.053	24.511	0.303	0.911	9.646	12.068
Digested		29.594	27.355	0.134	0.911	12.540	13.057
Coefficient		52.2	52.7	30.7	50.0	56.5	52.0
Animal 2							
In hay	36.000	32.814	30.071	0.670	0.986	9.641	15.253
In straw	36.000	32.728	29.923	0.252	1.037	12.787	14.522
Total	72.000	65.542	59.994	0.922	2.023	22.428	29.775
In feces	161.288	26.780	23.770	0.408	0.802	9.938	10.613
Digested		38.762	36.224	0.514	1.221	12.490	19.162
Coefficient		59.1	60.4	55.7	60.4	55.7	64.4
Dig. from hay		20.312	18.975	0.404	0.618	4.290	11.424
Dig. from straw		18.450	17.249	0.110	0.603	8.200	7.738
Coeff. of straw		56.4	57.6	43.7	58.1	64.1	53.3
Animal 3							
In hay	90.000	82.035	75.177	1.675	2.466	24.102	38.133
In feces	173.860	31.066	27.445	0.643	0.944	13.370	9.373
Digested		50.969	47.732	1.032	1.522	10.732	28.760
Coefficient		62.1	63.5	61.6	61.7	44.5	75.4
Animal 4							
In hay	90.000	82.035	75.177	1.675	2.466	24.102	38.133
In feces	190.970	32.279	28.689	0.689	0.925	13.578	10.144
Digested		49.756	46.488	0.986	1.541	10.524	27.989
Coefficient		60.7	61.8	58.9	62.5	43.7	73.4

TABLE 29.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY FOR HAY-STRAW-SILAGE COMBINATION—*Concluded*

(Collection period of 12 days; weights in kilogrammes; coefficients in per cent.)

	Original weights	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
			Period 4				
In feeds							
Oat straw	35.04	31.508	28.572	0.250	1.044	11.956	14.005
Corn silage	168.00	31.601	30.022	0.400	0.773	10.601	16.145
Total	203.04	63.109	58.594	0.650	1.817	22.557	30.150
In feces							
Animal 1	152.209	25.320	21.960	0.361	0.841	7.817	11.077
Animal 2	196.285	24.993	21.912	0.375	0.815	7.377	11.579
Animal 3	153.803	25.791	22.747	0.372	0.831	8.061	11.651
Animal 4	207.474	26.823	23.563	0.414	0.826	8.070	12.244
Digested							
Animal 1		37.789	36.634	0.289	0.976	14.740	19.073
Animal 2		38.116	36.682	0.275	1.002	15.180	18.571
Animal 3		37.318	35.847	0.278	0.986	14.496	18.499
Animal 4		36.286	35.031	0.236	0.991	14.487	17.906
Coefficients							
Animal 1		59.9	62.5	44.5	53.7	65.3	63.3
Animal 2		60.4	62.6	42.3	55.1	67.3	61.6
Animal 3		59.1	61.2	42.8	54.3	64.3	61.4
Animal 4		57.5	59.8	36.3	54.5	64.2	59.4
Coeff. of silage		64.9	66.7	49.1	75.5	67.4	67.9
Dig. from silage		20.509	20.025	0.196	0.584	7.145	10.962
Dig. from straw							
Animal 1		17.280	16.609	0.093	0.392	7.595	8.111
Animal 2		17.607	16.657	0.079	0.418	8.035	7.609
Animal 3		16.809	15.822	0.082	0.402	7.351	7.537
Animal 4		15.777	15.006	0.040	0.407	7.342	6.944
Coeff. of straw							
Animal 1		54.8	58.1	37.2	37.5	63.5	57.9
Animal 2		55.9	58.3	31.6	40.0	67.2	54.3
Animal 3		53.3	55.4	32.8	38.5	61.5	53.8
Animal 4		50.1	52.5	16.0	39.0	61.4	49.6

TABLE 30.—COMPOSITION OF FEEDING STUFFS IN PER CENT FOR HAY-CORN SILAGE RATION

Feed	Period	Moisture	Composition of dry matter				
			Ash	Protein*	Ether extract	Crude fibre	N-free extract
Hay	1	8.02	7.65	11.24	2.22	35.11	43.78
Hay	2	7.48	7.14	11.22	1.75	36.82	43.07
Corn silage	2	78.78	5.70	8.20	2.69	26.11	57.30
Corn silage	3	78.28	5.67	8.31	2.86	25.40	57.76

* N × 6.25.

TABLE 31.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY FOR HAY-SILAGE COMBINATION

(Collection period of 16 days for period 1, 12 days for periods 2 and 3; weights in kilogrammes; coefficients in per cent.)

	Original weights	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
			Period 1				
In hay							
All animals	116.000	106.70	98.530	1.919	2.366	37.457	46.713
In feces							
Animal A	275.225	46.05	40.977	0.873	1.224	18.619	16.061
Animal B	341.960	47.36	42.117	0.854	1.284	19.542	16.423
Animal C	277.124	47.61	42.452	0.884	1.241	19.681	16.501
Animal D	311.640	47.01	42.081	0.844	1.274	19.719	16.216
Digested							
Animal A		60.65	57.553	1.046	1.142	18.838	30.652
Animal B		59.34	56.413	1.065	1.082	17.915	30.290
Animal C		59.09	56.078	1.035	1.125	17.776	30.212
Animal D		59.69	56.449	1.075	1.092	17.738	30.497
Coefficient							
Animal A		56.8	58.4	54.5	48.3	50.3	65.6
Animal B		55.6	57.3	55.5	45.7	47.9	64.9
Animal C		55.4	56.9	53.9	47.5	47.5	64.7
Animal D		55.9	57.3	56.0	46.1	47.4	65.3
			Period 2				
In hay							
Animals A, B, D	60.000	55.512	51.546	0.996	0.972	20.442	23.904
Animal C*	55.000	50.886	47.251	0.913	0.891	18.739	21.912
In silage							
Animals A, B	180.000	38.196	36.018	0.506	1.026	9.972	21.888
Animal C	220.000	46.684	44.022	0.618	1.254	12.183	26.752
Animal D	240.000	50.928	48.024	0.674	1.368	13.296	29.184
Total ration							
Animals A, B	240.000	93.708	87.564	1.502	1.998	30.414	45.792
Animal C	275.000	97.570	91.273	1.531	2.145	30.927	48.664
Animal D	300.000	106.440	99.570	1.670	2.340	33.738	53.088
In feces							
Animal A	224.371	34.603	31.291	0.686	0.726	12.650	13.898
Animal B	268.341	36.435	32.767	0.696	0.764	13.499	14.156
Animal C	274.465	38.743	34.779	0.760	0.747	13.946	15.560
Animal D	344.728	42.417	38.339	0.799	0.756	15.859	16.949
Digested							
Animal A		59.105	56.273	0.816	1.272	17.764	31.894
Animal B		57.273	54.797	0.806	1.234	16.915	31.636
Animal C		58.827	56.497	0.771	1.398	16.981	33.104
Animal D		64.023	61.231	0.871	1.584	17.879	38.139
Digested from hay							
Animals A, B, D		31.031	29.639	0.548	0.456	9.874	15.562
Animal C		28.445	27.169	0.502	0.418	9.051	14.265

*Collection period of 11 days.

TABLE 31.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY FOR HAY-SILAGE COMBINATION—*Concluded*

(Collection period of 16 days for period 1, 12 days for periods 2 and 3; weights in kilogrammes; coefficients in per cent.)

	Original weights	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
			Period 2—Concluded				
Digested from silage							
Animal A		28.074	26.634	0.268	0.816	7.890	16.332
Animal B		26.242	25.158	0.258	0.778	7.041	16.074
Animal C		30.382	29.325	0.269	0.980	7.930	18.839
Animal D		32.992	31.592	0.323	1.128	8.005	20.577
Coeff. of silage							
Animal A		73.5	73.9	53.0	79.5	79.1	74.6
Animal B		68.7	69.9	51.0	75.8	70.6	73.4
Animal C		65.1	66.6	43.5	78.1	65.0	70.4
Animal D		64.8	65.8	47.9	82.4	60.2	70.5
			Period 3				
In silage							
All animals	300.000	65.151	61.458	0.864	1.863	16.553	37.632
In feces							
Animal A	128.586	20.718	18.750	0.385	0.427	6.192	9.835
Animal B	149.990	19.877	17.663	0.372	0.440	5.407	9.551
Animal C	136.644	22.313	19.865	0.400	0.441	6.400	10.604
Animal D	141.159	21.827	19.631	0.393	0.454	6.393	10.380
Digested							
Animal A		44.433	42.708	0.479	1.436	10.361	27.797
Animal B		45.274	43.795	0.492	1.423	11.146	28.081
Animal C		42.838	41.593	0.464	1.422	10.153	27.028
Animal D		43.324	41.827	0.471	1.409	10.160	27.252
Coefficient							
Animal A		68.2	69.5	55.4	77.1	62.6	73.9
Animal B		69.5	71.3	57.0	76.4	67.4	74.6
Animal C		65.8	67.7	53.7	76.3	61.3	71.9
Animal D		66.5	68.1	54.5	75.6	61.4	72.4